LETTER OF TRANSMITTAL.

HAWAII AGRICULTURAL EXPERIMENT STATION,
Honolulu, Hawaii, April 1, 1907.

SIR: I have the honor to transmit herewith and to recommend for publication the Annual Report of the Hawaii Agricultural Experiment Station for the fiscal year 1906.

Respectfully,

JARED G. SMITH,
Special Agent in Charge.

Dr. A. C. TRUE,
Director Office of Experiment Stations,
U. S. Department of Agriculture, Washington, D. C.

Publication recommended.
A. C. TRUE, *Director.*

Publication authorized.
JAMES WILSON,
Secretary of Agriculture.

CONTENTS.

	Page.
Summary of investigations. By Jared G. Smith	9
Field work and plat experiments	10
Potatoes	10
Roselle	10
Cotton	10
The orchard	11
Miscellaneous	11
Cooperative work	12
Grapes	12
Rubber	12
Tobacco	13
Coffee	14
Rice	15
Cacao and bananas	15
Chemical investigations	15
Entomological investigations	16
Horticultural investigations	17
Publications	17
Report of the entomologist. By D. L. Van Dine	18
Silk culture	19
Report of cocoons grown in 1905 experiment	19
Report of Clifton Silk Mills	20
Results of experiments in 1906	22
Report on Oro cocoons	23
Beekeeping	24
Mosquito control work	25
A partial list of the injurious insects of Hawaii, part 3	28
Sugar cane	28
Rice	29
Mulberry	29
Ceara rubber	29
Citrus trees	29
Mango	30
Banana	30
Grape	30
Miscellaneous	30
Accessions to entomological library relating to Hawaiian entomology	31
Report of the horticulturist. By J. E. Higgins	33
Citrus fruits	33
Mangoes	33
Distribution of Bluefields bananas	34
The roselle	34
Systematizing of records	34

Page.

Organic nitrogen in Hawaiian soils. By E. C. Shorey 37
Introduction 37
Nitrogen in Hawaiian soils 38
Our knowledge of soil nitrogen 41
Objects of study of soil nitrogen 43
Special soil studied 43
General properties of the soil 44
Decomposition products 45
Alkaline solution 51
Pyridin compounds in the soil ..... 5[illegible]
Neutral solution ..... 5[illegible]
Picolin carboxylic acid ..... 5[illegible]
Relation of pyridin compounds to agriculture ..... 5[illegible]
The economic seaweeds of Hawaii and their food value. By Minnie Reed ... 6
Methods of gathering limus 6
Native methods of preparing and serving limus for food 6
The most popular varieties of limus 7
Methods of preserving seaweeds 7
The limus most abundant and easily gathered 7
Native methods of cultivating limus 7
Value and amount of native seaweeds sold in Honolulu 7
Value of seaweeds imported by Orientals into Hawaii 7
Use of limus for medicine and incantations ..... 7[illegible]
Chemical analyses and comparative food values of seaweeds 7
Amount of gelatin or glue found in Hawaiian algæ ..... 7[illegible]
Hawaiian limus for making agar-agar for culture media 80
Further utilization of Hawaiian seaweeds for food, gelatin, farina, glue, and mucilage ..... [illegible]
Methods of preparing jellies, blancmange, soups, etc ..... [illegible]
Comparison of Hawaiian and Japanese species of economic algæ .....
Possibility of cultivating native, Japanese, Java, or Ceylon algæ in favorable localities on the Hawaiian or American coast .....
General summary of the possibilities of the seaweed industry .....
List of edible algæ of Hawaiian Islands .....

ILLUSTRATIONS.

Page.

PLATE I. Fig. 1.—Grapes growing at Honolulu. Fig. 2.—Grove of 7-year-old Ceara rubber trees 12

II. Fig. 1.—Abandoned coffee, Olaa. Fig. 2.—The Samoan cacao 14

III. Fig. 1.—Vegetation on virgin soil, 1,600 feet elevation, Hawaii. Fig. 2.—Picolin carboxylic acid from Pohakea soil 42

IV. Fig. 1.—Using glass-bottomed box to search for limu. Fig. 2.—Cleaning and preparing limu 64

V. Limu kohu, *Asparagopsis sanfordiana* 70

VI. Fig. 1.—Limu manauea, *Gracilaria coronopifolia*. Fig. 2.—Limu huna, *Hypnea* sp 70

VII. Fig. 1.—Limu pakaeleawaa, *Grateloupia filicina*. Fig. 2.—Limu akiaki, *Ahnfeldtia concinna* 70

ANNUAL REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION FOR 1906.[a]

SUMMARY OF INVESTIGATIONS.

By JARED G. SMITH, *Special Agent in Charge.*

The Hawaii Experiment Station has continued the policy of devoting its energies toward the diversification of agriculture in the Hawaiian Islands. During the period that has elapsed since the establishment of the station a number of agricultural industries have been begun or placed on a paying basis. Pineapple growing has been extended to include many large tracts, sisal production has been shown to be profitable, and tobacco raising has been demonstrated as practicable. In all of these enterprises the station has had a part, and the tobacco industry when developed will owe its inception to the investigations of the station.

Considerable work has been done in bringing more of the station land under cultivation in anticipation of the new water system provided for by Congress. About 10 acres of the lower portion of the station tract were cleared, fenced, plowed, and prepared for planting. As the station does not expect to plant all this at present, half the tract was cleared by the Territorial department of public works for the privilege of growing forage plants for a few seasons. In this way the station was relieved of the expense of removing a dense growth of lantana and guavas. The trial grounds of the station were completely fenced and a new slat greenhouse was constructed for the use of the horticulturist. A new stable was erected and a considerable amount of water pipe laid. An additional area, amounting to about 2 acres, on the higher portion of the station grounds was cleared and terraced by Japanese tenants at no expense to the station. The office and laboratory equipments were increased and numerous additions made to the station library by purchase, exchange, etc., so that now the station possesses the best collection of reference books on economic agriculture in Hawaii.

[a] This is the sixth annual report of this station. Previous reports will be found in U. S. Dept. Agr., Office of Experiment Stations Ann. Rpts. 1901, pp. 361–379; 1902, pp. 309–330; 1903, pp. 391–418; and 1904, pp. 361–382, and Bul. 170. A preliminary report on the agricultural resources and capabilities of Hawaii was published as Office of Experiment Stations Bul. 95.

FIELD WORK AND PLAT EXPERIMENTS.

POTATOES.

An attempt was made to demonstrate the possibility of growing early potatoes for the local market. About one-half an acre of land newly cleared of guava and lantana was planted to potatoes early in January, 1906. The plants were severely attacked by a form of rot and a very short yield was obtained. The crop was readily disposed of as new potatoes at 5 cents per pound, and the demand far exceeded the supply, thus demonstrating the presence of a local market capable of considerable development.

ROSELLE.

An experimental planting of roselle (*Hibiscus sabdariffa*) has been made each season for several years to demonstrate the value of this fruit for preserving, and to study methods of cultivation, insect enemies, and diseases. About one-fourth of an acre was grown this year, and a larger planting was made to carry the experiments through the coming year and to provide material for dissemination.

COTTON.

Several varieties of cotton were grown experimentally at the station during the past year, namely, Peruvian, from seed received from Mr. T. F. Sedgwick, formerly connected with the station, Carolina Prolific, Excelsior, Extra Long Staple, Sea Island, Russell Big Boll, Texas Bur, and King. The yield of the Upland varieties was not especially promising, but for the Peruvian and Sea Island the quality was good and the yield large. Samples of the different lots were submitted to the experts of the United States Department of Agriculture at Washington, and Mr. E. B. Boykin reported upon them as follows:

No. 1, Peruvian, seed from T. F. Sedgwick.—The length of lint of this specimen ranges from $1\frac{1}{8}$ to $1\frac{5}{8}$ inches; strength good; uniformity poor, the fibers very coarse to very fine, showing great variability in this respect. The drag is very strong, showing that the fibers are very crinkly, and should therefore possess good spinning qualities. The covering on the seed is remarkably heavy, indicating a very high per cent of lint. One fact which detracts from the value of this specimen is the very great variability in length and fineness of lint. Some locks are almost equivalent to the fineness of Sea Island, while others are no better than very ordinary Upland. It seems to afford an excellent opportunity for improvement by selection.

No. 2, Carolina Prolific.—Length of fibers from $\frac{3}{4}$ to 1 inch; uniformity fair; fineness medium; drag weak; strength poor; covering poor. This specimen should be classed as a rather poor Upland variety.

No. 3, Excelsior.—Length $\frac{3}{4}$ inch to $1\frac{1}{8}$ inches; strength fair; uniformity very good; drag weak; fibers coarse; covering fair. This should also be classed as ordinary American Upland short staple.

No. 4, Extra Long Staple Sea Island.—Length of fiber $1\frac{1}{2}$ to 2 inches; strength excellent; uniformity good; fineness excellent; drag strong; covering poor. The lint in this case is unusually fine. It seems to be quite as good as Sea Island.

No. 5, Russell Big Boll.—Length 1 to 1⅛ inches; strength poor; uniformity fair; fineness very poor; drag fair; covering fair. This should be classed along with some of the poorest short-staple varieties. The extreme coarseness of its lint is a very serious defect.

No. 6, Texas Bur.—This sample is very similar to No. 2, and can only be classed as an ordinary Upland.

No. 7, King.—Length ¾ to 1 inch; strength poor; uniformity fair; fineness very poor; drag weak; covering fair. This sample is an American Upland variety which is noted for its short, coarse lint, and which is adapted to the manufacture of coarse goods only.

THE ORCHARD.

An orchard of tropical fruit trees, including mangoes, avocados, bread fruit, cherimoyer, sapodilla, wi, custard apple, longan, and others, has been planted and will be extended as rapidly as seedlings or valuable varieties can be obtained. A nursery of citrus stock has been established to provide material for budding and grafting. The uncertainty of the station's water supply has in the past made permanent plantings impossible, but with the special appropriation provided by Congress it is believed that a supply of water will be developed sufficient to care for all the fruit trees planted on the lower portion of the station grounds.

MISCELLANEOUS.

Plantings have been made of about 4 acres of coffee and rubber trees on the middle portion of the station reservation and about 1 acre of coffee on the upper Tantalus ridge.

About 200 cuttings of vanilla were placed in a grove of Keawe. The plants have rooted nicely and may be expected to begin to bear in a year or more.

The Bluefields bananas that were imported by the station several years ago have been extensively propagated and about 1,000 suckers have been distributed among some fifty growers, and already very favorable reports concerning them have been received. As these bananas are now quite widely distributed, the station will not continue their propagation on as large a scale as formerly.

In January, 1906, 265 pounds of grass and other forage plant seed, collected on the ranges of southern Arizona, New Mexico, and elsewhere, was distributed to about fifty members of the Hawaiian Stock Breeders' Association. The collection included seed of white grama, gray weed, Japan fodder, winter orchard rye, side-oats grama, Spanish sulla, sainfoin, *Paspalum dilitatum* from Australia, and other varieties. Many of these grasses and forage plants are now well established on some of the island ranches, and it is believed that they will aid materially in restocking the ranges that have been overpastured.

A collection of limus, or edible seaweeds, was made in the shallow waters of the islands, and chemical studies and cooking experiments

performed with them in order to determine the extent to which it might be profitable to revive a former Hawaiian industry in these plants. The seaweeds which supply the agar-agar and Irish moss of commerce are fairly abundant in the island waters about Hawaii, and there appears to be no insurmountable difficulty against building up quite a local industry in the preparation of these marine food plants.

COOPERATIVE WORK.

GRAPES.

The growing of grapes has been followed to a limited extent in Hawaii for many years, but has never become what might be called an industry in any sense. On the island of Maui a rather extensive cooperative experiment in growing wine grapes has been begun. One hundred and seventy-seven varieties of wine grapes were planted by the station horticulturist in March, 1906, and the further expense of the investigation is to be paid by the owners of the vineyard. The growing of table grapes is carried on to a limited extent by some of the Portuguese settlers and others (Pl. I, fig. 1), and with the anticipated increase of immigrants from Spain, Portugal, and the Azores it is believed that grape growing and wine making will become profitable industries.

RUBBER.

An important experiment in rubber production has been begun at Nahiku, Maui, in cooperation with a rubber company. The growing of rubber-producing trees in Hawaii is not of recent introduction, as isolated trees of a number of the best known varieties are to be found here and there and in some places small groves exist that have suffered more or less from neglect. A number of companies have been recently organized for producing rubber, and the one cooperating with the station has set apart 1½ acres of land planted to rubber trees for experiments with fertilizers, variety tests, methods of tapping, preparation of rubber for market, etc. The difficulty of obtaining seeds of rubber trees and the low vitality of some shipments will make the extensive development of this industry rather slow. The station is cooperating with the Territorial board of agriculture and forestry in securing seed of the better known varieties. The question of growing the trees does not need demonstration, but the economic production of rubber remains to be investigated. One or two small groves of Ceara rubber trees large enough for tapping purposes have been located, and arrangements have been made to conduct careful experiments to determine the yield of these trees (Pl. I, fig. 2). These experiments will be extended as opportunity offers.

FIG. 1.—GRAPES GROWING AT HONOLULU.

FIG. 2.—GROVE OF SEVEN-YEAR-OLD CEARA RUBBER TREES.

TOBACCO.

The tobacco investigations carried on by the station are in cooperation with the Territorial board of agriculture and forestry, assisted by contributions from a number of individuals. The experiments with tobacco were begun in 1904, and in October, 1905, the first samples of Hawaiian-grown tobacco were submitted to expert judges for examination. Samples were sent to all parts of the mainland, and about 150 pounds were made up into cigars for distribution in Hawaii. The experts who examined the tobacco leaf are of the opinion that it is of good burn and flavor and that the elasticity, firmness, and general texture place all of the samples in the wrapper class.

The quality of the leaf is due to the soil and climate. The tobacco belt of Hamakua is coincident with that portion of the mountain slopes where the clouds gather almost every day in the year. The mornings are usually clear, with full sunshine, but before the heat of midday clouds drift in from the ocean and rest over the lower slopes, disappearing again toward evening. In effect the Hamakua tobacco is shade-grown, not by virtue of being planted under cloth tenting, but because of Mauna Kea's fog bank. It is a tenting that is rolled over the fields by nature's hand.

In February, 1906, a crop was planted on lot 17 Paauilo Homestead, this tract of 110 acres having been set aside by the Territorial commissioner of public lands for the use of the station for a period of three years. Five acres of abandoned coffee were cleared, part of the land plowed, and the balance merely hoed. Seed beds were started, and as rapidly as plants could be obtained these were transferred to the fields. The field work was begun so late that the cost was much greater than it should have been. Lumber was purchased, and a curing barn large enough to care for the crop of 5 acres was erected; but even with all the expedition the house was not ready in time to care for the first of the crop, and, as in previous years, a part was lost through its becoming overripe. The tobacco work for 1906 cost about $6,000, half of which was subscribed by three citizens of Hawaii.

The completion of the fiscal year 1906 thus saw a substantial beginning toward a trial of tobacco on a field scale. The tobaccos growing at that date were Sumatra, Turkish, Cuban, and various seed-leaf strains from Connecticut, Pennsylvania, and other tobacco-producing States. While the crop is not yet finished, the fermentation process not being completed, it has been pronounced by many experts to whom samples of the tobacco were submitted as of as good quality as any tobacco produced anywhere in the world. A German manufacturer who examined samples of our 1905 tobacco stated that in his opinion the Hamakua leaf is unexcelled in burning qualities, being superior in that respect to most mainland varieties, and that the mild flavor places it on an equality with the best Brazilian and some Cuban sorts.

A Philadelphia leaf buyer stated that the samples submitted to him were worth as filler 20 cents per pound unsorted. Small samples of wrapper were variously priced according to style and color at from 50 cents per pound up to $4.50 per pound.

The results of the 1906 crop are such that it will hardly be necessary to attempt any further demonstration on a field scale, but there are many points connected with the curing, fermenting, and sorting, and with the treatment of the plants in the field, on which the station could do good work, provided arrangements can be made to carry on such work in cooperation with growers. It has been demonstrated absolutely that tobacco of good burn, texture, flavor, and color can be produced on a commercial scale and probably at a very large profit in certain districts in Hawaii.

COFFEE.

In January, 1906, the special agent in charge of the station was requested by some of the coffee growers on the island of Hawaii to visit Washington, D. C., to work on their behalf in favor of the coffee industry, which is much in need of relief.

The coffee industry is one especially adapted to the development of a stable population of small landowners. The coffee belt lies at an elevation of from 1,000 to 3,000 feet, the most salubrious location in the islands, a region of comfortable temperatures the year around. Coffee does not require a large outlay of capital in its cultivation, and it is a crop which can be prepared for market without expensive machinery. When once prepared, it does not deteriorate, but, on the contrary, constantly improves with age, so that the producer is not subject to the great losses which frequently happen to those engaged in the production of perishable crops. There are no difficulties about growing coffee in Hawaii. The trees are remarkably free from disease, the yields are high, and returns sure. Coffee is a cash crop which can be drawn against as soon as a single bag is started on its ocean journey to the market. The chief cause of failure as regards coffee growing in Hawaii is due to economic conditions. The best grades of Hawaiian coffees have always been in demand, and these grades sell themselves. The low grades, however, can not be produced in competition with Brazil and similar countries, and practically every small producer engaged in coffee growing in Hawaii has been forced out of business (Pl. II, fig. 1). A few of the larger growers who remained have managed to continue only through the exercise of the most vigilant care and economy, and have held on more because they had faith in the future than on account of actual profits returned upon their investment.

Another factor affecting the coffee situation is that the character of the coffee trade as a whole is changing. The bulk of the coffee now

An. Rpt. Hawaii Agr. Expt. Station 1916.

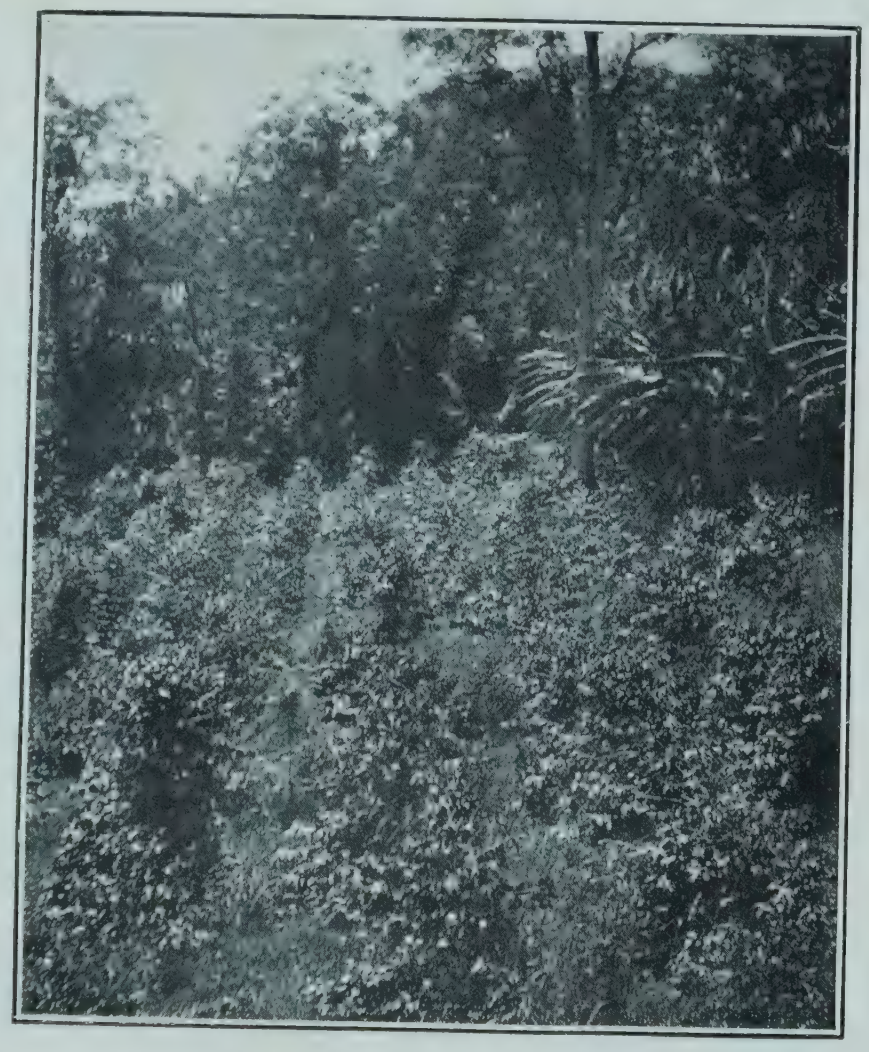


FIG. 1. -ABANDONED COFFEE, OLAA.

FIG. 2.—THE SAMOAN CACAO.

purchased by the consumer has been roasted or roasted and ground. This practice lends itself to the substitution of low grades for high grades, especially when coffee already ground is placed on the market. It is believed that a considerable quantity of coffee that under the old conditions would be unsalable is worked over and mixed with good grades in the so-called "package" coffees.

RICE.

Rice was formerly one of the important Hawaiian crops, but the industry has been in a bad way on account of increasing competition with rice from Japan, Louisiana, and Texas, and to some extent through the deterioration of the local product as well as the expensive methods of cultivation. Through the generous cooperation of several prominent estates a series of experiments was begun by the Hawaii station to determine what improvements in methods of cultivation, harvesting, fertilization, milling, breeding, and selection could be introduced to bring about the rehabilitation of the industry. Mr. F. G. Krauss, formerly in charge of the agricultural work of the Kamehameha schools, was secured to have this work in charge, and the lines of investigation planned embrace rice culture, breeding, and fertilization, and rotation of crops. Through the cooperation of the Bureau of Plant Industry of the Department of Agriculture 150 varieties of rice were obtained from different parts of the world for trial in comparison with the local varieties. These experiments have not progressed far enough to report definitely upon them, but it is believed that by improved methods of culture, the introduction of modern machinery, and the improvement of varieties it would be possible to restore rice growing to its former important position.

CACAO AND BANANAS.

The cooperative experiments with these two crops on the grounds of the Hilo Boarding School have been continued. Important collections of varieties of these plants, especially cacao (Pl. II, fig. 2), are desirable, and will be extended as rapidly as possible. The growth of the cacao during the past year was decidedly unfavorable, the poor results being attributed in a large degree to an unusual drought in a region which is generally considered as having exceedingly heavy rainfall. The bananas planted for shade have grown well and some varieties have fruited, so that the experiments can not be considered a failure, even though the results with cacao have not been very flattering.

CHEMICAL INVESTIGATIONS.

The work of the chemist has been divided between ordinary routine work and research investigations. Prominent in the routine work has been the completion of the analyses of some of the more important Hawaiian fodders and feeding stuffs, the results of the investigation

having been published in Bulletin 13 of the station. The most important result of this work was the establishment of the fact that many Hawaiian-grown fodders contain insufficient lime for the needs of live stock. Considerable interest on the part of stockmen has been shown in this work, and the feeding of bone meal with the other rations or mixed with salt is being practiced by some of them. Studies were made of a number of samples of soils to determine their adaptability for tobacco growing. Another line of work that seemed to offer opportunities for development was the utilization of various by-products as sources of alcohol. Studies were made of a number of these, among them the waste from pineapple canneries, bananas, ti root, etc., to determine their value for fermentation and distillation.

The research work was mainly along the same lines of investigation as those described in previous reports, namely, a study of the nitrogenous compounds in Hawaiian soils. These investigations have been carried forward to such an extent that the chemist has prepared a first report on them, which is given elsewhere (see p. 37). Some studies were begun on the manganese content of some of the soils of Hawaii, samples from Wahiawa, Oahu, containing as much as 10 per cent of that substance. A portion of the chemist's time was devoted to making dietary studies to determine the nutritive value of some of the foods used in Hawaii.

ENTOMOLOGICAL INVESTIGATIONS.

The station entomologist has devoted considerable attention to the preparation of a card catalogue of the literature relating to economic entomology of Hawaii and in extending the collection of insects of economic importance. The investigations carried on by him have been along lines of the control of insect depredations, of silk culture, beekeeping, and mosquito control. In cooperation with the station chemist studies were made of Hawaiian honeys to determine the sources from which they were gathered. Two new races of bees have been introduced during the year, and one gives promise of being better suited to Hawaiian conditions than the Italian bees now reared. The enemies and diseases of bees are being studied, with a view to including these topics in a contemplated report on the bee industry in Hawaii.

The silk work was along very much the same line as that described last year. Through the cooperation of the Bureau of Entomology of the U. S. Department of Agriculture, a quantity of eggs of the Oro race of silkworms was obtained and bred for comparison with the races previously reared. A detailed report of these investigations will be found elsewhere (p. 19).

The entomologist continues to act with the local committee in attempting to control the spread of mosquitoes about Honolulu. During the past year the most important work along this line was the successful

introduction of surface-feeding minnows to feed on the mosquito larvæ in fish ponds, taro fields, rice fields, and other places where draining and spraying are impracticable. A full report on their introduction is given on another page (p. 25).

HORTICULTURAL INVESTIGATIONS.

The horticulturist, in addition to caring for the nurseries and orchards and extending the collections as rapidly as possible, is devoting especial attention to the marketing of tropical fruits. Trial shipments of avocados were made to New York City in 1905 and other lots were successfully sent in cold storage on some of the army transports to Guam and Manila. Following the successes with these preliminary shipments, in June, 1906, preparations were made for an experiment with larger lots of pineapples, avocados, papayas, and bananas, and in August a shipment of about six tons of these fruits was made to San Francisco, accompanied by the horticulturist. The fruits were packed in various ways to determine the best method of commercial handling, and observations of the fruit were made between Honolulu and San Francisco to learn some of the transportation problems of the ocean voyage. A number of cities on the Pacific coast were visited and the fruits exploited. The tests were highly satisfactory, and it is believed that enlarged markets for these fruits are assured whenever regular supplies can be secured.

In this connection one of the first matters taken up in 1906 was that of a fruit-marketing association. Such an organization would enable the producer to secure more favorable selling prices, and it would also result in more regular supplies of fruit of uniform character. Considerable correspondence was carried on by the horticulturist with various fruit growers and shippers in the Hawaiian Islands with a view to the formation of such an association. While no definite results have as yet been obtained, it is believed that such an organization will shortly be formed.

PUBLICATIONS.

During the year the station issued the following publications:

Bulletin No. 11. The Black Wattle in Hawaii, by Jared G. Smith.

Bulletin No. 12. The Mango in Hawaii, by J. E. Higgins.

Bulletin No. 13. The composition of some Hawaiian Feeding Stuffs, by E. C. Shorey.

Press Bulletin No. 15. Lime an Essential Factor in Forage, by E. C. Shorey.

Press Bulletin No. 16. The Avocado Mealy-Bug, by D. L. Van Dine. This is an enlarged and revised edition of Press Bulletin No. 8, the supply of which had become exhausted.

In addition to these publications, the special agent in charge and various members of the staff have contributed articles along agricultural lines to the Hawaiian Forester and Agriculturist and the local press.

REPORT OF THE ENTOMOLOGIST.

By D. L. Van Dine.

As the entomological investigations of the station have progressed, certain lines have developed sufficiently to make a classification of the work possible. The more important lines are the injurious insects of the islands and their control; mosquitoes and their control; silk culture, and beekeeping. Along with these definite lines of work there is an amount of routine and miscellaneous work not easily classified. As heretofore, the entomologist has worked without an assistant, and would urge such an appointment as needful to the increasing demands made upon the station staff in general and the consequent development of this phase of the station work. A good equipment and working library are now at hand.

The correspondence is of a more satisfactory nature than during the first years of the station's existence. More cooperation is manifested in the problem of determining the sources of insect injury and the question of their suppression. This is due to a better understanding of the principles of insect control and the use of insecticides.

The work on the collection and records has been somewhat neglected during the past year and necessarily so in the face of more pressing duties. A permanent start has been made, however, and both phases of the work will receive more consideration when additional assistance is forthcoming. The collection of Coccidæ is especially complete, mounted in Riker mounts in connection with their food plants for exhibition purposes.

Aside from the annual report for the last fiscal year, the entomologist has published press bulletins Nos. 14 and 16 of the regular station series on Fuller's rose beetle (*Aramigus fulleri*) and the avocado mealy-bug (*Pseudococcus nipæ*), respectively. Many articles have also been supplied the local press and The Hawaiian Forester and Agriculturist on subjects relating to the entomological work of the station.

The field work has, as formerly, occupied a large amount of time. It is imperative that an intimate knowledge of the conditions in the varying localities of the islands be obtained at first hand to satisfactorily solve the problems that present themselves in carrying out the various projects. Many trips were made about the island of Oahu and one to the Hilo district, island of Hawaii, in the distribution of the top-minnows, which are discussed under the subject of mosquito control. One trip was made to the Nahiku district, island of Maui, to make an entomological inspection of the newly established rubber plantations in that locality. One trip was made to the Kohala district, island of Hawaii, in a survey of the insects injurious to field crops other than sugar cane on the homestead lands of that district.

Repeated trips were made to the outlying districts of Honolulu in the study of beekeeping and the distribution and life cycle and habits of the mango weevil (*Cryptorhynchus mangiferæ*).

The entomologist acknowledges gratefully many courtesies from colleagues throughout the country and abroad and would mention the help received from Dr. L. O. Howard and the other experts of the Bureau of Entomology in determinations of specimens and investigations in silk culture and beekeeping.

SILK CULTURE.

REPORT OF COCOONS GROWN IN 1905 EXPERIMENT.

Under date of November 6, 1905, the following letter was received from the Bureau of Entomology, United States Department of Agriculture:

DEAR MR. VAN DINE: In the temporary absence of Dr. L. O. Howard, I have to answer your letter of the 25th ultimo, which was received some time since, but has been held pending the arrival of the cocoons. These cocoons have just come to hand and are in excellent condition, and are well worthy of being graded as first-class. They are not, however, as fine as some specimens of Shensi cocoons received this season, yet are very superior to many others which have come to our notice. I think this lack of fineness is not due to lack of care, but to the moisture-laden air of the Islands; or, in other words, I think that the race is not well suited to your locality. Perhaps a Japanese race or a cross with a Japanese race would make a better cocoon. No reeling has yet been done to your cocoons, but I feel sure that a large percentage of floss or loose waste silk will result. We will advise you in this regard later.

So far as the price of cocoons goes, you must be aware that there is practically no market for them in the United States. We are trying to stimulate an artificial market by buying cocoons at from 90 cents to $1.15 per dried pound. This is slightly above the current European price. We also pay transportation under certain conditions. Our ability to purchase cocoons depends entirely upon Congressional action and therefore it is impossible to say how long we can continue to buy cocoons. I inclose herewith for your information a circular on silk culture which we are sending out very extensively, which will give you some idea of the lines we are following.

Our supply of silkworm eggs for next season's distribution has not yet been received from abroad, so we can not send you any more of eggs at this time. However, we will send you an ounce in the spring, just as soon as it is safe to do so.

We will reel your cocoons and return the raw silk to you, but I regret we will be unable to weave any of it into cloth, as we have no machinery for this latter process.

Very respectfully,

C. L. MARLATT,
Acting Chief of Bureau.

MR. D. L. VAN DINE,
Experiment Station, U. S. Department Agriculture, Honolulu, Hawaii.

Regarding the percentage of floss or waste silk resulting from the reeling mentioned in the above letter, Doctor Howard advised the writer under date of December 11, 1905, that "contrary to expectations, some of the results have shown a truly remarkable silk in many ways, especially in economy of reeling."

The detailed report on the cocoons was received under date of December 23, 1905, and is as follows:

DEAR MR. VAN DINE: I am returning you this day, by accompanying mail, the silk which has been reeled from your cocoons, less one skein, which was used in making tests. Please find inclosed a copy of a letter from Mr. James Chittick, secretary of the Clifton Silk Mills, Weehawken, N. J., relative to the qualities he found in your silk.

So far as your part is concerned the actual raising of the cocoons was certainly successful and you are to be congratulated with the splendid showing which they make. The strength and elasticity of the fiber and the very economical reeling results could not be bettered. Generally speaking it requires 4 pounds of dried cocoons to produce one pound of raw silk in the reeling; your cocoons produced 1 pound of silk to about 3 pounds of cocoons, which is equal to the most economical results obtained in experienced silk-producing countries. The weak places in the thread, causing numerous breaks, was entirely the fault of our reelers. Hairiness is due to the nature of the cocoon employed. We were well aware of this feature before sending you the eggs, but as the Sferici is a particularly hardy race and one safe to put into the hands of our inexperienced people, we have laid aside commercial qualities to some extent until a higher degree of proficiency should be attained by the producer and for this reason have distributed more eggs of the Sferici than of any other race. Commercially there is no comparison of this race with China and Japan silk. This feature is strongly brought out in the next phase—gumminess. Ordinarily the silk from your type of cocoon should have given a loss of 24 per cent in weight in the boiling-off process, due to the solubility of the gum. Actual tests showed a loss of 28 per cent, or 4 per cent in excess of the ordinary. This is no doubt due in great measure, if not entirely, to atmospheric conditions, and seems to show that the Sferici race, as stated in a previous letter, is not entirely suited to Hawaii. Japan silk loses 18 per cent and China silk 19 per cent in the boiling off.

In the eggs to be sent you in the spring I will try and select those of a race which seems better suited to Hawaii, though in this matter we must be guided mainly by experiment. Judging from results obtained in Hawaii between the years 1837 and 1842, by using a cross between the Canton white and yellow and the so-called American race, I am inclined to believe that by all means a cross race should now be used and that the Canton white or yellow be employed as a basis.

Yours, very truly,

L. O. HOWARD,
Chief of Bureau.

Mr. D. L. VAN DINE,
Experiment Station, U. S. Department of Agriculture, Honolulu, Hawaii.

REPORT OF CLIFTON SILK MILLS.

THE CLIFTON SILK MILLS, POST-OFFICE, WEEHAWKEN, N. J.,
Town of Union, N. J., December 16, 1905.

Dr. L. O. HOWARD,
Bureau of Entomology, U. S. Department of Agriculture, Washington, D. C.

DEAR DOCTOR HOWARD: I beg to report on the Hawaiian silk as follows:

The silk seems generally to have good strength and elasticity. It seems in places to be rather irregularly reeled, the result being that in the winding it breaks much oftener than it should.

This skein broke seventeen times in the winding, whereas silks that we are regularly handling would not break more than three times at the most. Still, it is only fair to say that as this skein had been opened and examined by us before putting on

the winding, it might have fared a little better in this respect had it gone directly on the machine. There were, however, scattered through it, weak places.

The size of the silk we make to be about 14 deniers. To get a proper judgment we threw this into two skeins of organzine and boiled off one of the skeins. The boiled-off skein weighed 786 grains and after boiling off weighed 565 grains, a loss of over 28 per cent. One per cent of this might be accounted for by soap and oil, and possibly there may have been some atmospheric difference between the time it was weighed in the thrown state and in the time it was weighed in the boiled-off state.

As we are returning to you the skein of organzine not boiled off, you can make yourself exact determinations in this respect from the former.

We do not think that the soap and oil put in here will amount to more than 1 per cent, as previously stated.

On putting some of this boiled-off silk on the testing reel for examination (in which state you can form a sounder opinion than you can before boiling off), we find that it makes a very fair organzine, being quite regular, with a good deal of elasticity, and fairly brilliant.

The main criticism to be made of it is its hairiness, and this is due principally or entirely to the nature of the cocoons.

For comparison, we would say that it is very similar to an Ardeche classical silk. Ardeche ranks in about the second grade of Cevennes silk, and classical, as you know, is the second classification. This hairiness is common to all Cevennes silks.

By getting European quotation on the grade above referred to you will therefore be able to arrive at a fair idea of its commercial value.

The Piedmont, China, and Japan silks are, of course, not so hairy, and this hairiness would make this silk unsuitable for some purposes.

I would suggest that you would find it of interest to wind a little, both of the boiled-off and the unboiled-off, and by then winding them onto a testing reel you will be able to get an excellent idea of the points above referred to.

Referring to what you say in your letter of November 16, I would state that a return of 1 pound of silk for 3 pounds of cocoons is a first-class return.

If there are any other points that you would like to be advised about in connection with this, I shall be pleased to take them up with you.

Very sincerely, yours, JAMES CHITTICK.

Regarding a market for dried cocoons, the following is quoted from the circular referred to in Mr. Marlatt's letter of November 6, 1905:

It is hoped that before long private enterprise will take up the matter of erecting silk-reeling plants, and thus create a permanent market for the cocoons. In the meantime, so long as Congress appropriates for the purpose, we will buy cocoons at from 90 cents to $1.15 per pound, at point of shipment, *for thoroughly dried cocoons.* Shipments weighing less than 4 pounds may be sent by mail, and for this purpose a Government frank will be provided on application, thus putting the shipper to no expense for transportation charges. Small lots of cocoons weighing something over 4 pounds may be divided into several shipments, each package being under a separate frank. Absolutely no cocoons must be sent by mail unless choked and dried. This is important, as otherwise there is liability of injury to other mail matter en route. Shipping by express has been found too expensive, and its use is now discouraged. Large shipments should all go by freight, *charges collect.* In no case where transportation is *prepaid* can the charges be refunded by this Bureau, neither will shipments by express be credited with expressage under any condition. We are operating a reeling plant at this office in order to convert cocoons into marketable raw silk.

From the above it is seen that persons producing even a small amount of cocoons can dispose of them at a price above the current European price *at point of shipment.* Anyone interested in the growing of silkworms should apply to the Secretary of Agriculture, Washington, D. C., for the Circular of Information in Regard to the Work in Silk Culture, and for Farmers' Bulletin No. 165, Culture of the Silkworm.

RESULTS OF EXPERIMENTS IN 1906.

On March 28, 1906, 1 ounce of eggs of the Oro race, a Chinese variety of silkworms, was received from the Bureau of Entomology, per the steamship *Alameda.* These eggs were forwarded from Washington, D. C., to Mr. E. M. Ehrhorn, deputy State horticultural commissioner, San Francisco, by mail on March 7, 1906. They were placed by Mr. Ehrhorn in cold storage aboard the steamer on March 15, 1906. On arrival in Honolulu the eggs were taken directly from cold storage aboard the steamer to the ice house of a meat company (temperature 42° F.). They were not exposed at once to hatch, since the mulberry trees had not at that time started to put out their new growth of leaves. This was unusual, but explained by the fact that there had been a drought of several months in length that had forced the trees into a semidormant state. On April 2 the eggs were inspected and the box found to contain many dead newly hatched worms. The writer could account for this state of affairs only upon the presumption that the development must have taken place en route from Washington to San Francisco, since the temperature on the steamer did not at any time exceed 40° F. The eggs were removed from the ice house at once and placed in an ice box at a temperature ranging between 50° and 60°. April 3 the eggs were exposed in the building used for the breeding purposes at a temperature ranging from 70° to 86° and the hatching began at once. Because of the shortage of the food supply only one-half of the eggs were retained for the experiment and the remaining half distributed to various parties who had from time to time requested eggs for breeding from an interest in the natural-history side. The hatching was very slow, and at the end of the fifth day, or on the morning of April 8, the remaining unhatched eggs, consisting of fully two-thirds of the half ounce, were thrown away. Despite the slow hatching the development was very regular, as shown by the following table. The date of hatching implies the worms hatched during twenty-four hours; for example, the hatching recorded on April 3 consists of the worms developing between 7 a. m. April 3 and 7 a. m. April 4.

Table showing hatching and development.

Date of hatching.	Molting periods.				Date of spinning.	Total life period (days).
	First.	Second.	Third.	Fourth.		
April 3	Apr. 10	Apr. 14	Apr. 19	Apr. 26	May 3	30
April 4	Apr. 11	Apr. 15	Apr. 20	Apr. 27	May 5	31
April 5	Apr. 12	Apr. 16	Apr. 22	Apr. 28	May 6	31
April 6	Apr. 13	Apr. 17	Apr. 23	Apr. 29	May 7	31
April 7	Apr. 14	Apr. 18	Apr. 24	May 1	May 8	31

The feeding table is incomplete, since at the beginning of the fourth age some of the worms had to be thrown away because of the shortage of the food supply; that is, less than one-sixth of an ounce of eggs were carried through to the cocoon stage. The amount of leaves fed is rather large, but it must be borne in mind that from the start the leaves were old and at every feeding there remained quite an amount uneaten to be thrown away.

Time of feeding and food consumed by silkworms from less than one-sixth ounce of eggs.

Date.	Times fed per day.	Amount consumed in 24 hours.		Date.	Times fed per day.	Amount consumed in 24 hours.		Date.	Times fed per day.	Amount consumed in 24 hours.	
		Lbs.	*Oz.*			*Lbs.*	*Oz.*			*Lbs.*	*Oz.*
April 3	7	0	⅛	April 16	7	2	0	April 29	6	16	0
April 4	7	0	2⅛	April 17	7	2	8	April 30	6	16	0
April 5	7	0	7	April 18	7	3	1	May 1	5	20	0
April 6	7	0	8¾	April 19	6	3	0	May 2	5	22	0
April 7	7	0	12	April 20	6	4	0	May 3	5	25	0
April 8	7	0	12	April 21	6	5	0	May 4	5	31	0
April 9	7	1	0	April 22	6	6	0	May 5	5	35	0
April 10	7	1	0	April 23	6	6	0	May 6	5	20	0
April 11	7	1	0	April 24	6	7	6	May 7	5	18	0
April 12	7	1	8	April 25	6	10	0	May 8	5	10	0
April 13	7	1	8	April 26	6	10	0	May 9	5	5	0
April 14	7	1	8	April 27	6	13	0				
April 15	7	2	0	April 28	6	12	0	Total		314	1¾

The temperature ranged from 86° maximum to 65° minimum, with a mean maximum of 82.32° and a mean minimum of 67.62°; also during the above time the sky averaged part cloudy, with twelve clear days.

REPORT ON ORO COCOONS.

Under date of June 26, 1906, the following report was received from the Bureau of Entomology, United States Department of Agriculture:

DEAR MR. VAN DINE: Referring to my letter to you of the 22d instant, I beg to state that Mr. Gilliss reports as follows on your cocoons:

It is thought that the Oro Chinese race as a basis for crossing with other races may produce a cocoon particularly adapted to Hawaii. While the cocoons sent by you are somewhat undersized, they are of a very good quality, indeed, and contain a fair amount of silk. Of course, owing to adverse circumstances under which your worms were raised, it is hardly possible to consider this rearing as a fair test. We find it almost impossible to furnish you with silkworm eggs in good condition, owing to the length of journey and varying temperatures to which the eggs are necessarily

subjected en route. It is thought that you should be able to obtain eggs in better condition by shipping directly from the sericulture establishments of Japan and China. We are glad to know that the eggs furnished by us have proved to be healthy. The hatching of a certain proportion of the larvæ en route is a matter we can not control, as the journey between Washington and San Francisco must be performed without the use of cold storage.

The photographs are very interesting to us. We note that you use swinging shelves, presumably to guard against mice, ants, or other vermin, and we consider this an excellent idea. I might suggest, however, that, instead of the close-bottomed box used, it might be better to use something which would tend to ventilate the bed whereon the worms are being reared. Especially is this true during a moist, warm spell of weather, when the leaves tend to ferment and mold. Much attention has been paid by us to this point during the last season.

While we can not supply you with the number of mulberry trees which you would require in the carrying on of your work, we may be able next fall to send you several thousand seedlings of the best white mulberry if you wish.

Tests will be made within a short time regarding the length and strength of the fiber of your cocoons, and we will then take pleasure in advising you of results.

Yours, very truly,

F. H. Chittenden,
Acting Chief of Bureau.

Mr. D. L. Van Dine,
Hawaii Experiment Station, Honolulu, Hawaii.

BEEKEEPING.

The investigations relating to apiculture in Hawaii have been continued along the lines detailed in the project of this station on the subject. Two queens representing the Cyprio-Carniolan and Cyprio-Caucasian crosses, respectively, were received from the Bureau of Entomology and introduced in the apiary of a company on the island of Oahu. While a definite opinion can not be given at this time on the value of these bees as compared with the bees already established here, it can be said that they are at least as vigorous and industrious as our best Italians. Further introductions of desirable races and crosses are planned in cooperation with the Office of Apiculture, Bureau of Entomology.

Hawaii is particularly fortunate in that neither European nor American foul brood—serious diseases in most beekeeping sections of other countries—have not as yet gained a foothold in our apiaries. Suitable legislative action will be recommended to the next Territorial legislature to prevent, if possible, the introduction of these diseases or to deal with them should they unfortunately become established. As to enemies, none of serious consequence have been observed. Both the diseases and the enemies of bees will be carefully worked out and considered in a forthcoming bulletin on the industry.

The source and chemical characteristics of Hawaiian honeys have been little understood up to this time. This phase of the project has and will continue for some time to take up the greater part of the time

devoted to this part of the entomological investigations of the station. Up to the close of this fiscal year thirty-three samples of honey have been collected of which the source has been determined. These samples have been handed to the chemist of the station for analysis. The writer estimates that fully twice this number must be worked out before the completion of the survey of the sources of Hawaiian honey. In this connection, the question of introducing desirable bee plants for pasturage will receive attention.

The writer has been successful in forming a temporary organization of the beekeepers for the purpose of effecting a permanent association whose object will be the development of apiculture in Hawaii.

MOSQUITO CONTROL WORK.

Work along the line of this project has been confined almost entirely to the breeding and distribution of the top-minnows introduced from Texas during the early part of this fiscal year. To briefly summarize: The question of introducing special mosquito-eating fish to feed on the larvæ of mosquitoes in such collections of water as taro patches, rice fields, irrigation ditches, reservoirs, seacoast swamps, etc., was taken up with Dr. David Starr Jordan by the writer in the early part of 1903. Doctor Jordan recommended the top-minnows found in the Mississippi Valley, Florida, the Gulf States, and Mexico. The cost of the undertaking prevented anything from being done until a visit of Doctor Jordan to the islands made a personal interview on the subject possible. Doctor Jordan offered to send an expert from Stanford University to collect the fish and import them, providing the Territory would pay the expenses of the undertaking. During the session of the legislature in 1904 the matter was presented to the governor and received his indorsement, with the result that an item of $1,500 for "Expenses, importation of fish for the destruction of mosquitoes," was appropriated. The legislature placed the item in the regular bill of expenses of the Territorial board of health, and accordingly that body had the disbursement of the money. Doctor Jordan selected Mr. Alvin Seale to undertake the work, and the writer procured the privilege of using a portion of a rice field on the country estate of Hon. S. M. Damon, at Moanalua for a breeding place, and therein prepared the breeding ponds to receive the fish.

The following report from Mr. Seale gives the method employed in collecting the fish and transporting them to the islands:

HONOLULU, HAWAII, *September 23, 1905.*

Mr. D. L. VAN DINE,

Entomologist, U. S. Experiment Station, Honolulu, Hawaii.

DEAR SIR: In accordance with the following letter to yourself from Dr. David Starr Jordan I was chosen to attempt the introduction of "top-minnows," or

"killifish," into the Hawaiian Islands, for the purpose of destroying the larvæ of mosquitoes:

LELAND STANFORD JUNIOR UNIVERSITY,
OFFICE OF THE PRESIDENT,
Stanford University, Cal., April 18, 1905.

Mr. D. L. VAN DINE,
United States Experiment Station, Honolulu, Hawaii.

DEAR SIR: The best place to collect the fishes which you want would doubtless be in Louisiana. It would probably take no longer time to bring them from there than from any other places nearer. Perhaps an equally good place would be Tampico, on the edge of Mexico. You understand that this would necessarily be an experiment. These little fishes feed freely on mosquitoes. Some live in brackish water, some in fresh water, and all of them are very hardy; but no one has ever tried to transplant any of them, and the whole thing might turn out, for some reason or other, to be a failure. Especially one would need to experiment on feeding the little fishes during their transportation. The genera which I would recommend are Mollienesia, Adinia, Gambusia, and Fundulus. Some of these are viviparous; others lay eggs. Whoever undertakes this should give a good deal of attention to the question of feeding the little fishes, and for this purpose, perhaps, a tank breeding mosquitoes would be as good as anything. The best time to undertake it would be about the 1st of June. I will select some one as soon as I hear from you.

Very truly, yours, DAVID S. JORDAN.

On receipt of yours of July 11, 1905, with the advance of $500 of the Territorial appropriation covering the expenses of this undertaking, I started from Stanford University to the Southern United States. It was my intention to secure the top-minnows at or near New Orleans, but the rigid quarantine in operation in Louisiana prevented my carrying out this plan. Seabrook, near Galveston, Tex., was then selected as the next place most available. At Seabrook I found the family of top-minnows, Pœciliidæ, in large numbers. They were swarming in all the stagnant waters at sea level as well as in various ditches, ponds, and standing pools. Mosquitoes are very plentiful in and about Seabrook, but after a study of the situation I am convinced that their source is not the bodies of water containing these fish but rather temporary and artificial breeding places, such as closed pools, tubs, tin cans, and other refuse which are not accessible to these fish.

As per his letter to you, Doctor Jordan recommended the following genera: Mollienesia, Adinia, Gambusia, and Fundulus. These are all members of the single family Pœciliidæ, or top-minnows. I first made a careful examination of a number of the stomachs freshly taken from members of the above genera. The stomach contents was found to consist largely of larvæ of various insects, including those of mosquitoes, egg masses of mosquitoes, minute crustaceæ, and some vegetation. The results showed that Gambusia were the best insect feeders. Of 100 stomachs of this genus examined, all contained many insect larvæ and eggs, among which I noticed especially numerous egg masses of the mosquito. However, Mollienesia, Fundulus, and Gambusia differed slightly in regard to their capacity for the various insect larvæ, and the difference was probably due to the different food localities. The temperature of the water in and about Seabrook in which these fish were found ranged from 74 to 87°.

It now remained to determine under what conditions the fishes could be most successfully transported to Hawaii. Six ordinary 10-gallon milk cans were prepared by puncturing the covers with numerous holes and placing the cans in bran sacks, the intervening space being tightly packed with Spanish moss. This served to keep the water at an even temperature. Two hundred fish were placed in each can. The

following morning so many were dead that it was evident the cans were overcrowded, and I reduced the number to 100.

Experiments were conducted as follows:

Can No. 1: Allowed to stand undisturbed. Water unchanged and unaerated. Temperature normal. The first morning 6 fish were dead. The second day 2 died. The third day the fish were perfectly lively and were taking food freely. The fifth day 5 died, and by the eighth 20 had died. The experiment was not carried further.

Can No. 2: Water changed once each day. Temperature normal (ranged from 74 to 78°). During the first three days there were 4 deaths. The eighth day 2 died. After this time there were no more deaths. Fish fed freely on mosquito larvæ and prepared fish food.

Can No. 3: Water changed twice each day. Temperature normal. Three deaths the first night. After this time there were no more deaths. Fish fed freely on mosquito larvæ and prepared fish food.

Can No. 4: Water changed every two days. Temperature normal. Five deaths the first three days, after which no fish died. Fish fed freely, keeping constantly at top of the water.

Can No. 5: Water slowly and very gradually reduced in temperature to 40°. Fish would not feed at the end of six days. During this time 18 had died. Experiment discontinued.

Can No. 6: Water reduced slowly to freezing point, then can packed in ice. At the end of six days all but 3 of the fish were dead. Experiment discontinued.

The above experiments demonstrated that the fish should be transported in water at the normal temperature and gave the necessary information in regard to the frequency of changing the water.

The three most abundant species, *Gambusia affinis*, *Fundulus grandis*, and *Mollienesia lattipinna*, were collected and approximately 75 placed in each can. On September 4, 1905, I left Seabrook, Tex., on the long journey to Honolulu. A 20-gallon tin tank was taken along as a supply reservoir.

The following routine work was observed during the entire trip: At 8 a. m. the fishes were fed sparingly on prepared fish food, finely ground liver, or hard boiled eggs; at 9.30 half the water in each can was siphoned off from the bottom, thus cleaning out the cans and removing all uneaten food and excrement, and an equal amount of fresh water added; at noon the cans were all aerated by means of a large bicycle pump, a sponge being tied over the end of the hose to separate the air into fine particles; at 4 p. m. 2 gallons of water was siphoned off from the bottom and 2 gallons of fresh water put in; just before retiring the cans were again aerated by means of the air pump.

At each place en route where the water was changed it was first tested by placing two fish in a bucket containing the new water at the proper temperature. At El Paso, Tex., only, did the water kill the fish thus treated. After ten minutes the two fish were dead, probably due to the alkali the water contained. The water at Los Angeles was good, as also the San Francisco water, which was used from the latter place to Honolulu, an abundant supply being carried on the steamer. The water used from El Paso to Los Angeles was taken from the supply tank, filled at San Antonio, Tex.

Twelve fish died between Galveston and San Francisco, and only 15 between San Francisco and Honolulu. The fish were landed in Honolulu from the steamship *Alameda* on September 15, 1905, the trip from Texas occupying twelve days and 27 of the approximate 450 fish were lost.

The fish were in fine condition on arrival and, as prearranged by yourself, were placed in the breeding ponds prepared for them. The temperature of the water about Honolulu is almost identical with that where the fish were collected, and the

appearance of the fish at this writing indicates that they should thrive on the islands. The fish should be confined in the present breeding ponds, where they can be prevented from going out to sea or falling prey to other fish until their increased numbers permit general distribution to other localities in the group.

Very truly, yours,

ALVIN SEALE,
Assistant, U. S. Fish Commission.

The fish were divided into four lots and planted in as many places on the island of Oahu. In three places they were given their freedom under conditions distinctly different, and in the fourth place they were confined, namely, in the breeding ponds at Moanalua. The multiplication of these fish has been very rapid. Many hundreds have been distributed from the breeding ponds to various localities under varying conditions for observational purposes. The conditions under which they best thrive and the places best suited for them have been determined as a guide for their establishment throughout the islands. It is only a question of a few years when the shallow waters of the group, embracing the larger number of the natural collections of water where mosquitoes breed, will be teeming with these hardy, effective enemies of the mosquito larvæ. One point in this connection must be strongly emphasized—that is, that relief in towns, cities, and closely settled communities is dependent upon direct, active measures of control, since, in the main, the source of mosquitoes infesting closely settled districts is artificial collections of water, such as tubs, tanks, cesspools, discarded tins and bottles, gutters, water traps, and small ponds and ditches of a temporary character, or any collection of water not accessible to these fish. Relief implies general organized inspection and remedial work.

As stated in the 1905 report of the entomologist, organized effort to rid the islands of mosquitoes has ceased. This was due to the failure of the last legislature to provide the necessary funds to carry out the plans promulgated by the citizens' mosquito committee of Honolulu. The Territorial board of health, relying on money from private sources, has carried on control work in Honolulu and other districts of the islands, notably Hilo, as actively as the money available for the purpose would permit.

A PARTIAL LIST OF THE INJURIOUS INSECTS OF HAWAII, PART 3.

(Continued from Office of Experiment Stations Bulletin No. 170, 1906.)

SUGAR CANE.

The sugar-cane aphis (*Aphis sacchari*). Observed by Koebele in the cane fields of the islands of Oahu, Maui, and Kauai in 1896. At times appears in destructive numbers in certain localities, but not generally so. The ladybird beetle (*Coccinella repanda*) is a very

important enemy of this species. The writer is indebted to Mr. G. W. Kirkaldy for the determination of the sugar-cane aphis.

A longhorned grasshopper (*Xiphidium varipenne*). This species eats to some extent the leaves of cane, doing no serious damage. Mr. Otto Swezey has clearly pointed out during the year the remarkable fact that this species devours the sugar-cane leaf-hopper in sufficient numbers to consider the grasshopper of benefit in the cane fields. Injurious to the flowers of rice.

RICE.

Mole cricket (*Gryllotalpa africana*). Frequents wet places, feeding on the root system beneath the surface of the ground. Is injurious also to taro and sugar cane.

A longhorned grasshopper (*Xiphidium varipenne*). Feeds to slight extent on the margin of the leaves of rice, but the more serious damage to the crop is in gnawing through the glumes to obtain the pollen, on which it feeds extensively during the flowering season.

A shorthorned grasshopper (*Oxya velox*). Feeds to some extent on the leaves of rice.

The rice weevil (*Calandra oryzæ*). A very common pest of stored products generally in Hawaii. The species is reported to infest the grain in the field before harvesting. This insect is very destructive to stored corn in the Kula district, island of Maui. Occurs in various foodstuffs aside from rice, especially flour, meal, breakfast foods, etc.

The rust-red flour beetle (*Tribolium ferrugineum*). Infests flour, meal, and rice. Taken also during the year in large numbers from fish guano and bone meal fertilizers.

The cadelle (*Tenebroides mauritanicus*). Taken in large numbers last year from bone meal and fish guano fertilizers. Reported as infesting stored rice.

MULBERRY.

The following scale insects infest the mulberry in Hawaii: *Pseudococcus nipæ*, *Pseudococcus filamentosus*, and *Saissetia* sp.

CEARA RUBBER.

A scale insect (*Saissetia nigra*) and a mealy bug (*Pseudococcus* sp.) were collected from Ceara rubber trees on the island of Kauai.

CITRUS TREES.

The orange aphis (*Myzus citricidus*). Very abundant and especially destructive to young growth. The species was recently described as new by Mr. G. W. Kirkaldy.

SCALE INSECTS, COCCIDÆ:

Chrysomphalus aonidum, collected during the year from orange. Found also on Allamanda and palms (*Pritchardia* spp.).

Pulvinaria psidii, on lime.

Pseudococcus filamentosus, at times very abundant. Especially injurious to young growth. The ladybird beetle (*Cryptolæmus montrouzieri*) is an important enemy of this scale.

Coccus viridis. Specimens of this scale were received from Mr. Jacob Kotinsky, collected from the "Giant lemon" at Honaunau, Kona district, island of Hawaii.

MANGO.

An undetermined lepidopterous larva was observed during the year destructive to the flowers of the mango and injuring partly developed fruit by feeding on the epidermis of mangoes in close contact in the cluster, between which the insect was hidden.

SCALE INSECTS, COCCIDÆ.

The mango scale (*Coccus mangiferæ*).

The Florida red-scale (*Chrysomphalus aonidum*).

Coccus longulus.

BANANA.

The scale insect (*Saissetia nigra*) was collected from the fruit and leaves of the banana during the year.

GRAPE.

The Japanese beetle (*Adoretus umbrosus tenuimaculatus*).

Fuller's rose beetle (*Aramigus fulleri*).

Lepidopterous larva (undetermined) observed by Mr. Jared G. Smith at Makawao, island of Maui, feeding on the stems of undeveloped fruit, causing the same to drop from the cluster.

SCALE INSECTS, COCCIDÆ.

The avocado mealy-bug (*Pseudococcus nipæ*).

Pseudococcus filamentosus.

MISCELLANEOUS.

The bean weevil (*Bruchus obtectus*) was taken from the seed pods of Klu (*Acacia farnesiana*).

The scale *Phenacaspis eugeniæ* is very common on oleander.

ACCESSIONS TO ENTOMOLOGICAL LIBRARY RELATING TO HAWAIIAN ENTOMOLOGY.

[This list is supplemental to the bibliography of Hawaiian entomology in the Report of the Entomologist for 1905 (Office of Experiment Stations Bul. 170). In the latter the references in the station library are marked with an asterisk (*).]

Bates, G. W. Sandwich Island notes. New York, 1854, pp. 174, 175, 203, 280, 288, 318, 362, 432, 434.

Blackman, L. G. The menace of insect pests to agriculture. Hawaiian Forester and Agr., 2 (1905), No. 12, pp. 377–387.

———. Hawaiian Entomological Society. Hawaiian Forester and Agr., 3 (1906), No. 3, pp. 93–95.

———. Insect pests. Hawaiian Forester and Agr., 3 (1906), No. 4, pp. 115, 116.

Craw, Alexander. Fighting insect pests with insects. Hawaiian Forester and Agr., 2 (1905), No. 11, pp. 321–325.

———. Report of the superintendent of entomology. Hawaiian Forester and Agr., 3 (1906), Nos. 2, pp. 59–61; 6, pp. 187–189; 7, pp. 197–199; 8, pp. 249–253.

———. Report of the superintendent of entomology and inspector. Rpt. Bd. Comrs. Agr. and Forestry, Hawaii, 2 (1905), pp. 99–112. (October, 1906.)

Evans, Walter H. The green bug, *Lecanium viride*. Hawaiian Forester and Agr., 3 (1906), No. 1, pp. 27–29.

Giffard, W. M. Division of entomology. Hawaiian Sugar Planters' Expt. Sta. Rpt. 1905, pp. 5–7.

Higgins, J. E. Citrus fruits in Hawaii. Hawaii Expt. Sta. Bul. 9, 1905, pp. 25–28, pl. 2, fig. 7.

———. The mango in Hawaii. Hawaii Expt. Sta. Bul. 12, 1906, pp. 24, 25, pl. 3.

Howard, L. O. Breeding beneficial insects. Science, n. ser., 22 (1905), No. 562, p. 468.

Kellogg, V. L. American insects. New York: Henry Holt & Co., 1905, pp. 308 and 451.

———. Yellow fever and the Panama Canal. Science, n. ser., 23 (1906), No. 577, p. 114.

Kirkaldy, G. W., and Swezey, Otto H. Proceedings of the Hawaiian Entomological Society, 1 (1905), pp. 36, pls. 2.

———. Leaf-hoppers and their natural enemies (IX, Leaf-hoppers—Hemiptera). Hawaiian Sugar Planters' Expt. Sta., Div. Ent. Bul. 1, pt. 9, pp. 271–479, pls. 21–32. (February 3, 1906.)

Knab, Frederick. The yellow-fever mosquito. Science, n. ser., 23 (1906), No. 581, pp. 270, 271.

Kotinksy, Jacob. Entomological notes. Hawaiian Forester and Agr., 2 (1905), Nos. 9, pp. 266–269; 10, pp. 295–299; 11, pp. 361–364; 12, pp. 397–404; 3 (1906), Nos. 1, pp. 8–11; 2, pp. 53–57; 4, pp. 117, 118; 6, pp. 185–187; 7, pp. 200, 201.

——— and Newell, M. The Japanese beetle fungus. Hawaiian Forester and Agr., 2 (1905), No. 11, pp. 361–364.

———. Report of the assistant entomologist. Rpt. Bd. Comrs. Agr. and Forestry, Hawaii, 2 (1905), pp. 113–166. (October, 1906.)

Krauss, F. G. The vegetable garden. Hawaiian Forester and Agr., 2 (1905), Nos. 4, pp. 95–97; 11, pp. 356, 357.

Marcuse, Adolf. Die Hawaiischen Inseln. Berlin, 1894, pp. 140, 141.

Norgaard, Victor A. Horn flies on sheep. Rpt. Bd. Comrs. Agr. and Forestry, Hawaii, 2 (1905), pp. 211, 212. (October, 1906.)

———. The screw worm fly. Rpt. Bd. Comrs. Agr. and Forestry, Hawaii, 2 (1905), pp. 212–218. (October, 1906.)

Perkins, R. C. L. The introduction of benficial insects into the Hawaiian Islands. Nature [London], 55 (1897), No. 1430, pp. 499, 500.

———. Notes on Hawaiian wasps with descriptions of new species. Trans. Ent. Soc. London, 1902, pt. 2, pp. 131–140.

———. Four new species and a new genus of parasitic Hymenoptera from the Hawaiian Islands. Trans. Ent. Soc. London, 1902, pt. 2, pp. 141–143.

———. On the generic characters of Hawaiian Crabronidæ. Trans. Ent. Soc. London, 1902, pt. 2, pp. 145–148.

———. Report of the division of entomology. Hawaiian Sugar Planters' Expt. Sta. Rpt. 1905, pp. 29–38.

———. Leaf-hoppers and their natural enemies. Hawaiian Sugar Planters' Expt. Sta., Div. Ent. Bul. 1, Introduction, pp. I–XXXII, May 1, 1906; pt. 4 (Pipunculidæ), pp. 123–158, pls. 5–7, September 9, 1905; pt. 6 (Mymaridæ, Platygasteridæ), pp. 187–205, pls. 11–13, November 13, 1905; pt. 8 (Encrytidæ, Eulophidæ, Trichogrammidæ), pp. 241–267, pls. 18–20, January 6, 1906); pt. 10 (Dryinidæ, Pipunculidæ), pp. 483–499, pls. 33–38 March 1, 1906.

Seale, Alvin. Introduction of top-minnows into Hawaii. Hawaiian Forester and Agr., 2 (1905), No. 11, pp. 364–367.

Smith, Jared G. Silk. Hawaii, its agricultural possibilities. Honolulu: Hawaii Promotion Committee, 1906, pp. 17, 18.

———. Beekeeping. Hawaii, its agricultural possibilities. Honolulu: Hawaii Promotion Committee, 1906, p. 20.

———. Injurious insects in Hawaii. Hawaii, its agricultural possibilities. Honolulu: Hawaii Promotion Committee, 1906, pp. 21, 22.

———. The Black wattle in Hawaii. Hawaii Agr. Expt. Sta. Bul. 11, 1906, p. 16.

Swezey, Otto H. Leaf-hoppers and their natural enemies. (VII, Orthoptera, Coleoptera, Hemiptera.) Hawaiian Sugar Planters' Expt. Sta., Div. Ent., Bul. 1, pt. 7, pp. 211–238, pls. 14–17. (December 30, 1905.)

———. Observations on insects during a recent trip on Hawaii. Proc. Hawaiian Ent. Soc., 1 (1905), pp. 16–19.

Terry, F. W. Leaf-hoppers and their natural enemies. (V, Forficulidæ, Syrphidæ, Hemerobiidæ.) Hawaiian Sugar Planters' Expt. Sta., Div. Ent., Bul. 1, pt. 5, pp. 163–181, pls. 8–10. (November 13, 1905.)

———. Preliminary account of insects of economic importance in the Hawaiian Islands (Diptera). Hawaiian Forester and Agr., 3 (1906), No. 2, pp. 35–45.

Van Dine, D. L. The mango weevil, *Cryptorhynchus mangiferæ*. Pacific Commercial Advertiser, Honolulu, August 11, 1905, p. 3.

———. Fuller's rose beetle, *Aramigus fulleri*. Hawaii Expt. Sta. Press Bul. 14, 1905, pp. 8, fig. 1.

———. The introduction of the mango weevil. Hawaiian Forester and Agr., 2 (1905), No. 10, pp. 313–315.

———. The melon fly, *Dacus cucurbitæ*. Hawaiian Forester and Agr., 3 (1906), No. 4, pp. 127–129.

———. Mosquito control work in Hawaii. Paradise of the Pacific, May, 1906, pp. 10–13, ill.

———. Silk culture in Hawaii. Pacific Commercial Advertiser, Honolulu, July 2, 1906, p. 106.

———. Beekeeping in Hawaii. Pacific Commercial Advertiser, Honolulu, July 2, 1906, p. 105.

———. The avocado mealy-bug, *Pseudococcus nipæ*. Hawaii Expt. Sta. Press Bul. 16, 1906, pp. 12, figs. 3.

———. The mango weevil, *Cryptorhynchus mangiferæ*. Hawaii Agr. Expt. Sta. Press Bul. 17, 1906, pp. 11, pls. 2.

———. Report of the entomologist. Report on Agricultural Investigations in Hawaii, 1905, U. S. Dept. Agr., Office of Experiment Stations Bul. 170, 1906, pp. 38–59.

REPORT OF THE HORTICULTURIST.

By J. E. Higgins.

CITRUS FRUITS.

The quality of the imported citrus fruits is in striking contrast with the excellency of those grown here and which may be picked from the trees in some part of the islands almost every day in the year. It is without exaggeration to say that by multiplying some of the Hawaiian seedling oranges the season could be extended to include almost the whole year in most localities. Lemons in several varieties, limes unsurpassed anywhere, and seedling pomelos that compare favorably in flavor with budded fruit are to be found in the gardens of Honolulu and other parts of Hawaii. To assist and encourage the further cultivation of these fruits the station published in the early part of the year Bulletin No. 9, "Citrus Fruits in Hawaii," which contains cultural instructions relating to soils, propagation by seeds, budding and grafting, irrigation, fertilizing, pruning, etc. Since the publication of the bulletin some interesting forms have been observed which are not there recorded. An orange has been noted which has a decided tendency toward the navel type and lacks nothing in flavor.

The citrus nursery at the station contains stocks of several species which are ready for budding.

MANGOES.

Bulletin No. 12, "The Mango in Hawaii," has also been published during the year and contains cultural instructions, methods of propagation, description of a large number of varieties, and notes on insects and diseases. The mango is destined to become one of the important tropical fruits of the American markets. That it can be shipped in cold storage has already been demonstrated, and the West Indies will probably supply the eastern markets in the near future. Hawaii should supply the Pacific slope with mangoes and even send some as far east as Chicago.

There is but one serious obstacle which may hinder this Territory from building up a large and important mango industry. The presence of the mango weevil (*Cryptorhynchus mangiferæ*) in Hawaii will be a serious hindrance to the progress of the industry so long as its ravages remain unchecked. All fruit which is under the suspicion of containing this insect will most certainly be quarantined. It is the important duty of the Territory in its own interests to take most stringent measures to control and destroy this insect. It is a duty also to the whole American mainland, since the insect is one that is likely to be introduced in hand baggage, or even in pockets, in spite of the most rigid inspection. A few thousand dollars spent now in efforts to stamp out the pest would mean a saving of millions in the future.

This station is making a collection of trees of all the finest varieties available and will propagate them on seedling stock.

DISTRIBUTION OF BLUEFIELDS BANANAS.

The Bluefields bananas which were introduced in cooperation with the Territorial board of agriculture and forestry have been cared for and multiplied sufficiently to warrant a general distribution throughout the island group. Over 500 suckers and large corms have been distributed, which would probably be equivalent to fully 1,000 suckers. These have been placed in lots of from 2 or 3 to 50, the size of the lot being determined by the locality and the facilities offered for cultivation. The distribution has been made with the understanding that those who have received the plants will care for the same, noting their growth and production and reporting from time to time. It has further been agreed that the Government shall receive from each grower a number of plants equal to that given if at any time in the future such should be needed for a further distribution. This variety of bananas, as has been stated in previous reports, was introduced because of certain advantages which it holds as a commercial banana. It is more easily shipped and is the variety which is best known in the American markets.

THE ROSELLE.

Among the plants which have been cultivated in the experimental plats during the year is the roselle (*Hibiscus sabdariffa*). The fleshy calyx of this fruit and the seed pod while young and tender are used in the manufacture of very excellent jam and jelly. The experiments conducted show the plant to be well adapted to local conditions. It produces a heavy yield of fruit per acre, amounting to 6,000 or 7,000 pounds under average conditions. The plant will tolerate a reasonable amount of dry weather, but responds freely to the application of water and produces more heavily. The seed is sown about March and the plants reset in the field when about 6 or 8 inches high, at distances about 4 by 6 feet if irrigation is to be practiced or if rainfall is abundant. In dry localities 4 feet by 4 feet will be sufficient. A new crop of larger area has been planted to continue the experiments through the coming year.

SYSTEMATIZING OF RECORDS.

Photographic records.—The photographs of the horticultural work have been indexed so as to make them readily available. All negatives have been filed in drawers in an index case and have been numbered consecutively in different series, determined by the size of the negative. One print from each negative has been mounted on especially prepared sheets and filed by subjects in a loose-leaf binder.

The number corresponding to that of the negative is placed under the print. By reference to this number the negative can be found immediately. The subject index is provided so that in a very few minutes it is possible to determine just what photographs are in the station file on any subject. This has already been of great convenience and should prove more valuable as the number of photographic records increases.

Records of plants.—The system followed in recording the planting of seeds, cuttings, tubers, etc., and of growing plants received from outside sources, has been simply that of consecutive numbering in an accession book where the date of planting is also recorded, the same number being placed upon labels in the pots, flats, or field. A card index arranged alphabetically has been made for convenient reference to plants in the propagating houses or fields. The cards contain the scientific name, the common name, if any, the variety, the date of planting, the sources from which received, the places where planted, and other important data.

The following is a list of some of the accessions which have been made during the year ending June 30, 1906:

Accessions by the horticultural department, 1906.

Scientific name.	Common name, or variety.	Remarks.
Citrus aurantium sinensis	Hawaiian summer orange	
Passiflora quadrangularis	Granadilla	
Mangifera indica	Mango	For stock in nursery.
Manihot glaziovii	Ceara rubber	Germination test.
Mangifera indica	Mango	Seeds of selected varieties.
Do	do	Experiments with position of placing seeds.
Persea gratissima	Avocado	Nursery stock.
Nephelium litchi	Litchi	Do.
Ananas sativus	Natal pineapple	S. P. I. 9634.[a]
Thysanolæna agrostis	Ornamental grass	S. P. I. 14922.
Coffea liberica	Liberian coffee	
Musa sapientum	Banana Manzano	From Porto Rico Experiment Station.
Do	Banana Puano	
Do	Banana Morado Blanco	
Do	Banana Johnson	
Do	Banana Morado	
Do	Banana Datil	
Do	Banana Macho	
Nephelium longana	Longan	
Coffea sp	Harras coffee	S. P. I. 11354.
Anona cherimolia	Cherimoyer	S. P. I. 9466.
Quebrachia lorentzii		S. P. I. 6345.
Erythroxylon coca		S. P. I. 6447.
Cissus sp		S. P. I. 7383.
Harpephyllum caffrum	Kafir plum	S. P. I. 9616.
Mimosa afzalioi		S. P. I. 3783.
Erythrina canna		S. P. I. 3787.
Tamarindus indicus		S. P. I. 3780.
Ficus carica	Caprifig	S. P. I. 6780.
Carica quercifolia		S. P. I. 8960; produces the vegetable pepsin of commerce.
Garcinia sp		S. P. I. 9569.
Cæsalpinia gilliesii		S. P. I. 8935.
Maytenus boaria		S. P. I. 8921.
Grabowskia glauca		S. P. I. 8956; hedge plant.
Anacardium occidentale	Cashew	S. P. I. 12809.
Psidium sp	Guava	S. P. I. 11726; a large red variety.
Mangifera sp	The Saigon mango	S. P. I. 11645.
Psidium sp	Guava	S. P. I. 13803; an Argentine guava.

[a] Seed and Plant Introduction Number, U. S. Department of Agriculture.

Accessions by the horticultural department, 1906—Continued.

Scientific name.	Common name, or variety.	Remarks.
Santalum album	White sandalwood	
Mimusops elengi		
Erythrina suberosa		
Bixa orellana		
Pentzia virgata		A composite, valuable as fodder.
Mangifera indica	Douglas Bennett's Alphonse mango.	S. P. I. 8727.
Do	Totafari	S. P. I. 8732.
Spondias lutea		S. P. I. 9009.
Musa sp	Banana	S. P. I. 13568.
Palisota bartori		
Eriodendron anfractuosum		S. P. I. 14813
Strychnos nux vomica		
Musa sumatrana	Ornamental banana	
Musa rhodochlamys	do	
Musa superba	do	
Carica papaya pyriformis	Papaya	
Musa ornata rosea	Ornamental banana	
Musa religiosa	do	
Musa martinii	do	
Musa gillettii	do	
Acacia giraffæ		
Acacia semperflorens		
Asparagus plumosus blampiedii		
Asparagus plumosus nanus		
Asparagus springeri		
Asparagus decumbens		
Hibiscus rosa-sinensis	Punicens (?)	
Bauhinia montana		
Bauhinia purpurea		
Bauhinia esculenta		
Ipomœa umbellata	Morning-glory	
Ipomœa setosa	do	
Kickxia elastica	Silk rubber	
Citrus decumana		
Psidium cattleyanum	Strawberry guava	
Coffea arabica	Coffee	From Cape Verde Islands.
Gloxinia hybrida robusta		
Nicotiana sanderæ		
Monstera deliciosa		S. P. I. 15673.
Do		From local plants.
Brachychiton populneus	Carryong tree	
Diospyros ebenaster	Sapote, negro wood	
Ipomœa batatas	Sweet potato	21 varieties.
Persea indica		S. P. I. 16133.
Coffea zanguebariæ		S. P. I. 12897.
Vanilla planifolia	Vanilla	
Ricinus lauricariensis		
Castilloa elastica	Central American rubber tree	
Canavalia sp		S. P. I. 17957.
Bauhinia kurgii		S. P. I. 17955.
Eugenia punicifolia		S. P. I. 17956.
Anona muricata	Soursop	
Artocarpus incisa	Breadfruit	
Artocarpus integrifolia	Jackfruit	
Chrysophyllum cainito	Star apple	
Citrus medica limon	Sicily lemon	
Cucurbita lagenaria villosa		
Cucurbita sp		S. P. I. 15937.
Agave rigida elongata	Henequen	
Crotalaria juncea		
Vitis spp	Grapes	About 100 varieties of wine and table grapes.

ORGANIC NITROGEN IN HAWAIIAN SOILS.

By E. C. Shorey,[a] *Chemist.*

INTRODUCTION.

The importance of the nitrogen problem in agriculture has never been more generally recognized than at the present time.

A recent writer on the subject has stated that the nitrogen in the air covering 5 acres of the earth's surface is equal to that contained in 1,000,000 tons of nitrate of soda, the amount consumed annually in Europe.[b]

Briefly stated, the nitrogen problem is as follows: So far as known none of the higher plants constituting ordinary agricultural crops obtain their nitrogen in any other way than through the soil. The nitrogen of the soil has been at some time the free nitrogen of the air. The processes by which this free nitrogen has become fixed in the soil are not all definitely known. It is known, however, that they are slow. Of the elements taken from the soil by plants there is, as a rule, in the soil and the rocks from which soils are being formed an abundant supply of those of a mineral nature. Moreover, these elements after the growth and consumption of a crop find their way for the most part back to the soil. On the other hand, the nitrogen taken from the soil by growing plants is ultimately in large part returned to the air as free nitrogen.

We have, then, two cycles of an opposite nature. The mineral ingredients of rocks become part of the soil, are taken up by plants, and then by decay or consumption by man or animals are returned to the soil to begin the cycle again. With nitrogen we have the free nitrogen of the air becoming fixed in the soil by slow natural processes, then becoming a part of growing plants, and on the decay or consumption of these plants becoming again free nitrogen of the air.[c] The nitrogen problem arises because under the conditions incident to civilization this cycle is not balanced. The growing of crops, the feeding of stock, and man return free nitrogen to the air faster than the processes of nature fix it in the soil again. The problem, then, is

---

[a] Transferred to Bureau of Soils, U. S. Department of Agriculture, December 8, 1906.

[b] P. A. Guye, Paper read before the Swiss Society of Natural Science, 1906.

[c] The statement given above of the relation of plants to the nitrogen of the atmosphere is intended to be most general in character. The cycles are seldom as simple as stated, and the contention made by T. Jamieson (Agr. Research Assoc. [Scot.] Rpt., 1905, pp. 81) that plants utilize the free nitrogen of the air through specialized hairs on the leaves is ignored as not being proven.

how to aid or supplant nature's processes and fix or render available for the growth of plants the free nitrogen of the air by artificial means.

There is no doubt that this problem will be solved. It has been attacked from several points by many workers, and along two lines progress has been made to the extent that the problem now is to reduce the cost of production.

There is, however, one phase of the nitrogen problem which has not received the attention it warrants. Many soils contain relatively large amounts of nitrogen. On many such soils containing nitrogen sufficient for many crops it has been found profitable to use nitrogenous fertilizers. This is usually explained by stating that the soil nitrogen is not available.

There are in Hawaii thousands of acres of which the soil contains 20 tons of nitrogen per acre-foot, and a pertinent question in this connection is, why apply nitrogenous fertilizers to such soils; or, to put the question in another form, why can not some of this nitrogen stored in the soil be made to perform the functions of the nitrogen applied in fertilizer, whatever these may be? To answer these and many other questions suggested by this condition, it is necessary to know something about the nitrogenous compounds in the soil. When, however, we face this question, we find that there is absolutely no definite knowledge regarding the chemical composition or constitution of these bodies.

With the belief that how to utilize the nitrogen already in the soil is an important phase of the nitrogen problem, and with the aim to add something to our knowledge of the chemical composition and constitution of the nitrogenous compounds in the soil the soil studies of which the present paper is the first part were undertaken.

NITROGEN IN HAWAIIAN SOILS.

Hawaiian soils differ from those of the American mainland in several respects. Maxwell[a] has pointed out some of these, particularly the highly basic character of Hawaiian soils. Among the important points of difference is one which may be a difference of degree rather than of kind. This is the large amount of organic matter and nitrogen contained in them. Many analyses of Hawaiian soils, by several methods, have been made, but few have been published. Among the general statements regarding the average nitrogen content of Hawaiian soils which have been published the following are the most important. Eckart[b] states the average nitrogen content of Hawaiian cane soils as follows: Oahu, 0.119 per cent; Maui, 0.222 per cent; Kauai, 0.246 per cent;

[a] Lavas and Soils of the Hawaiian Islands, Honolulu, 1898.

[b] Hawaiian Sugar Planters' Sta., Div. Agr. and Chem. Bul. 15, p. 7.

and Hawaii, 0.388 per cent. Maxwell[a] states the average nitrogen content of upland and lowland cane soil to be upland, 0.456 per cent; lowland, 0.195 per cent. In a later publication the same writer[b] gives the average nitrogen content of 48 samples of cane soil from districts on Hawaii as follows:

Average nitrogen content of Hawaiian soil.

District.	Number of samples.	Nitrogen.
		Per cent.
Kohala	19	0.515
Hamakua	14	.572
Hilo	6	.633
Do	2	.840
Kau	7	.482

Hartmann has published analyses of 12 samples of soil from the plantation of the Onomea Sugar Company on Hawaii, showing a nitrogen content ranging from 0.56 per cent to 0.89 per cent.[c]

Soils above the elevation at which cane is grown are, as a rule, still higher in nitrogen. This is particularly true of the upland soils of Hawaii. Maxwell[d] states the average nitrogen content of the coffee lands in this section to be 1.237 per cent.

The writer has examined soils as to their nitrogen content, from the upper lands throughout the Territory, the amount ranging from 0.30 per cent to 2.20 per cent; and it is thought that a conservative estimate of the nitrogen content of the uplands in cultivation is somewhat as follows. The upland soils on the islands other than Hawaii contain from 0.3 per cent to 0.5 per cent nitrogen, the upper cane soils and those of the adjoining coffee lands on the windward side of Hawaii contain from 0.75 per cent to 1.25 per cent nitrogen, and limited areas on Hawaii contain as much as 2.2 per cent.

The organic matter in these soils as determined by loss on ignition is proportionately high, and the same is true of the humus as determined by the chemical methods at present in use.

As is usually the case with highly organic soils these are very retentive of moisture. Soils containing 10 to 12 per cent humus, which corresponds roughly to 0.75 per cent to 1.0 per cent nitrogen, generally contain when air dried 15 per cent to 20 per cent moisture. The determination of moisture in soils of this character, by loss in weight on drying at 100° C., has been checked in a number of cases by passing a current of dry air through the soil at 100° C. and then into a drying tube containing strong sulphuric acid. The moisture determined by increase of weight of the drying tube has agreed with the loss in

[a] Lavas and Soils of the Hawaiian Islands, p. 67, Honolulu, 1898.

[b] Hawaiian Sugar Planters' Sta., Div. Agr. and Chem. Bul. 2, p. 3.

[c] Hawaiian Planters' Mo., 16 (1897), p. 171.

[d] Lavas and Soils of the Hawaiian Islands, p. 67, Honolulu, 1898.

weight of the soil; the sulphuric acid was not colored and did not contain nitrogen, showing that the loss in weight is not organic matter.

While soils unusually high in nitrogen are very common in Hawaii, there are also some very low in this constituent; some containing as little as 0.05 per cent. These soils are found, for the most part, on the lowlands, especially on Oahu, and some cane lands of this character are the most productive in the Territory if not the most productive in the world. While the productiveness of these soils is no doubt in a large measure due to favorable conditions, such as temperature, texture of soil, absence of high winds, and abundant irrigation, no one who has followed their development can doubt that it is also due in no inconsiderable part to the use of fertilizers, especially the application of nitrate of soda.

The scientific investigation of Hawaiian soils has, up to the present time, been confined almost altogether to those devoted to the growth of cane, and as a result of the work of the experiment station of the Hawaiian Sugar Planters' Association fertilizers are now used almost universally on Hawaiian sugar plantations. Nitrogenous fertilizers constitute a considerable portion of those used. For the crop of 1903 Hawaiian planters used 6,000 tons of nitrate of soda and 2,500 tons of nitrogen in other forms.[a]

Crawley[b] says more is spent in Hawaii for nitrogenous fertilizers than for all others combined.

Most of the land in Hawaii available and suitable for crops such as coffee, tobacco, pineapples, etc., is above the cane level and relatively of high nitrogen content. Now, in view of the fact that planters on the lowland find it profitable to use large quantities of nitrogenous fertilizers, what is the proper course for the grower of other crops on the uplands, where thousands of tons of nitrogen are apparently locked up in the soil?[c]

---

[a] C. F. Eckart, Hawaiian Sugar Planters' Sta., Div. Agr. and Chem. Bul. 9, p. 62.

[b] Hawaiian Planters' Mo., 25 (1906), p. 222.

[c] The average weight of an acre of Hawaiian soil to the depth of 1 foot is 3,888,000 pounds. (J. T. Crawley, Hawaiian Planters' Mo., 21 (1902), p. 359.) Using this weight as the basis of calculation we have the following figures:

Nitrogen per acre-foot of Hawaiian soil.

Nitrogen soil.	Nitrogen per acre-foot.	Equivalent in nitrate of soda per acre-foot.
Per cent.	*Pounds.*	*Pounds.*
0.05	1,944	14,034
.10	3,888	28,068
.50	19,440	140,340
1.00	38,880	280,680
2.00	77,760	561,360

Or, assuming that the nitrogenous compounds in the soil contain the same amount of nitrogen as protein, we have for 1 per cent nitrogen in the soil 126 tons of nitrogenous compounds per acre-foot.

Viewed from the standpoint of the cane planter, this problem presents itself somewhat as follows: If on a soil containing 0.1 per cent or less nitrogen three or four times as much sugar is produced as on a soil containing 0.1 per cent to 1 per cent; and if in the first case large amounts of nitrogenous fertilizers have been found to be an important factor in producing the crop, may one not temporarily neglect the other factors and ask something about the nitrogen already in the soil in the latter case? Some of the questions which this view of the problem suggests are: (1) In what form does the nitrogen occur in these soils? (2) Can it be converted into nitrates; and if so, under what conditions? (3) Is any of it available in organic form or in any form other than nitrates? (4) Does it occur in any form injurious to plant life?

OUR KNOWLEDGE OF SOIL NITROGEN.

These questions at once suggest the more general one: How much do we know about the nitrogen in the soil? If an attempt is made to answer this question with regard to Hawaiian soils, we find that, despite the fact that there has been little or no investigation of the organic matter in these soils, our knowledge of the composition and constitution of the organic or nitrogenous bodies in them is just as extensive and accurate as that of these bodies in soils elsewhere. In other words, our knowledge of the composition and constitution of these bodies is of the most general nature and may be said to apply to all soils.

Our knowledge of the nitrogenous bodies may be stated shortly as follows: In most soils there is, under ordinary conditions, some nitrogen present as nitrates. This amount is always small and is a constantly fluctuating quantity. There is also in most soils a small amount of nitrogen present as ammonium compounds, and under certain conditions a small amount may be present as nitrites. The amount of nitrogen present as nitrates, ammonia, and nitrites probably seldom exceeds 5 per cent and more often is not 1 per cent of the total. The remainder is organic, and a portion of this is what is known as humus nitrogen.

The term humus as used by agricultural chemists is the name applied to the dark-colored organic matter extracted from the soil by alkaline solutions. The method at present in use for determining humus is essentially that of Grandeau,[a] who applied the term "matière noir" to the extract.

In this extract certain acids—humic, ulmic, crenic, and apocrenic—have been said to exist, but, viewed in the light of modern organic chemistry, these compounds are wholly without standing. A number of chemists have given the percentage composition of these supposed acids, but no two agree. Nothing is known as to their constitution,

[a] Traité d'analyse des matières agricoles, p. 148. Paris, 1877.

the presence of the carboxyl group essential to the constitution of an organic acid has never been demonstrated, and all the evidence is to the effect that they are not acids. The lack of standing of these compounds is concisely stated by Cameron[a] as follows: "The existence itself of these acids has never been demonstrated. * * * No satisfactory description of the physical or chemical properties of these supposed acids, their salts, or characteristic derivatives, have been recorded." This statement can not be controverted, and yet in spite of this we find in nearly every treatise on soils from Mulder in 1840 to the present these acids are spoken of with the same assurance that one would speak of citric, tartaric, or any other organic acid the constitution and derivatives of which are well known. Even so recent a writer as Hilgard[b] uses the names of these supposed acids in this way.

It has been customary for chemists to determine humus by extracting the soil with ammonia and to determine the humus nitrogen in a similar extract made with caustic soda, to obviate the difficulty of distinguishing between the nitrogen of the soil and that of the ammonia when it is used as a solvent. Rimbach[c] has, however, shown that these two solvents do not extract the same amounts of nitrogen from the soil, the greater amount being extracted by caustic soda. This fact is one indication of the complex nature of the soil extract known as humus. The certainty of its complexity is emphasized when we consider that humus is the result of the decay of living tissues in the soil, and is simply a stage in the resolution of living matter into free nitrogen, carbonic acid, and ash ingredients, from which it was formed.

Soil humus, then, may be defined as a group of complex organic bodies containing nitrogen which can be extracted from the soil by dilute alkalis. Some of the bodies in this extract can be precipitated by dilute acids, which precipitate can be dissolved again by alkalis. Some of the bodies included in this group seem to be capable of entering into combination with mineral ingredients in the soil and others have the power of holding, in a form little soluble in water, both mineral and organic compounds which otherwise are freely soluble. In short, humus is a name for a group of bodies of which we know very little, and this meager knowledge is remarked in nearly every work on agriculture. For instance, King[d] says: "The humus of soils so far as its chemical composition is concerned is not well understood." Storer[e] says: "Little is known as yet as to the precise chemical composition of humus."

---

[a] U. S. Dept. Agr., Bureau of Soils Bul. 30, p. 39.

[b] Soils, pp. 126, 322. New York and London, 1906.

[c] Journ. Amer. Chem. Soc., 22 (1900), p. 695; California Sta. Rpt. 1899–1901, pt. 1, p. 43.

[d] The Soil, p. 94. New York and London, 1897.

[e] Agriculture In Some of its Relations with Chemistry, Vol. II, p. 187. New York, 1897, 7th ed.

FIG. 1.—VEGETATION ON VIRGIN SOIL, 1,600 FEET ELEVATION, HAWAII.

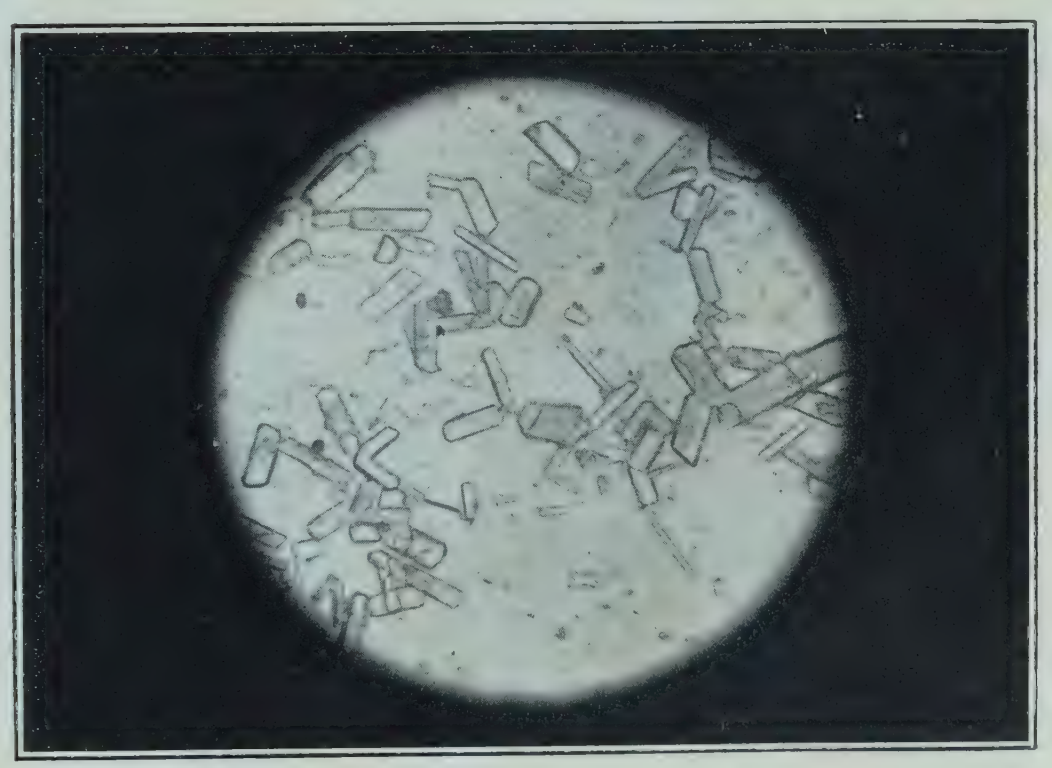


FIG. 2.—PICOLIN CARBOXYLIC ACID FROM POHAKEA SOIL.

There is always a considerable portion of the organic soil nitrogen that is not extracted by alkaline solutions, or is not humus nitrogen as the term is ordinarily used. Of this portion, which often amounts to 50 per cent of the total, still less is known than of humus nitrogen. This group of organic bodies has been given no group name and has been practically ignored, except that it has been considered unavailable in distinction to humus nitrogen as available.

OBJECTS OF STUDY OF SOIL NITROGEN.

The objects in mind in undertaking a study of the nitrogenous compounds in Hawaiian soils were—

(1) To determine more definitely than is now known the chemical composition and constitution of the group of bodies known as humus.

(2) To determine the identity and constitution of organic nitrogenous bodies other than humus.

(3) To determine to what extent the bodies studied under (1) and (2) can be nitrified and under what conditions.

(4) To determine whether organic nitrogenous bodies in the soil can be directly assimilated by plants.

(5) To determine whether any organic nitrogenous bodies in the soil are poisonous or injurious to plants.

SPECIAL SOIL STUDIED.

In attempting to carry out the work so planned it was decided to confine the preliminary work to one soil, typical of a large area fairly high in nitrogen. For this purpose soil was chosen from Pohakea, Hawaii, at an elevation of 1,600 feet (Pl. III, fig. 1). The analysis of this soil by official methods gave the following figures:

Mechanical analysis.

[Soil passed 2-millimeter sieve and analysis calculated to soil free of water and organic matter.]

	Per cent.
Fine gravel, 1–2 mm	25.772
Coarse sand, 1–0.5 mm	17.697
Medium sand, 0.5–0.25 mm	10.498
Fine sand, 0.25–0.1 mm	21.856
Very fine sand, 0.1–0.05 mm	13.018
Silt, 0.05–0.005 mm	9.129
Clay, 0.005–0.0001 mm	2.030

Chemical analysis.

[Soil passed 0.5 millimeter sieve.]

	Per cent.
Moisture	19.540
Organic matter and combined water	28.360
Insoluble	19.320
Iron and alumina	28.797
Lime	.300

	Per cent.
Magnesia	0.631
Sulphuric acid	.343
Phosphoric acid	.703
Potash	.077
Nitrogen	.728
Humus	12.470
Humus nitrogen	.560

Larger samples taken at a later date showed some variation from these figures, the nitrogen varying from 0.700 per cent to 1.010 per cent.

The location of this soil is in the coffee district on the windward side of the island of Hawaii. The samples were taken from land which had been cleared a short time, but had borne no crop. Land in this section before clearing is covered with a tangled growth of ferns, tree ferns, and forest trees, chiefly ohia (*Eugenia malaccensis*), and the soil has been formed in place by the decay of this luxuriant vegetation mixed with the disintegrated lava which forms the basis of all Hawaiian soils. This district is on the rainy side of the island, but is subject at times to severe drought. A record of the rainfall for the last ten years at 1,450 feet elevation a few miles from this location shows the following figures: Highest annual rainfall, 275.46 inches in 1902; lowest, 52.62 inches in 1897; highest monthly rainfall, 93.39 inches in March, 1902; lowest, 0.09 inch in December, 1899. A period of drought occurred in 1901, the rainfall being, May, 0.46; June, 0.21; July, 1.07; August, 0.26, and September, 0.70 inches. In the following year the rainfall for the same months was, May, 29.88; June, 12.65; July, 2.48; August, 32.62, and September, 8.06 inches.

The temperature in this district, as throughout the Territory, is fairly equable, seldom being as low as 55° F. or higher than 85° F. The formation of a soil rich in nitrogen and organic matter under such conditions is somewhat at variance with the generally accepted ideas regarding such soils. Theoretically, one might expect, with a moderate to high temperature, heavy rainfall alternating with dry weather, and a porous, easily drained soil, that the organic matter resulting from vegetable decay would rapidly disappear or be resolved into its elements as the final stage of such decay. That such has not been the case indicates some organic form very resistant to further action by the agents active in the soil. Whether this resistant form is one depending on organic constitution, one of combination with the mineral ingredients of the soil, or one of absorption is of course not known.

GENERAL PROPERTIES OF THE SOIL.

In addition to the general properties already noted this soil presents the following general characteristics:

Solubility.—The behavior of the nitrogenous compounds with regard to a number of solvents is shown by the following figures, the

nitrogen dissolved being stated as per cent of the soil. The soil was that which passed a 1-millimeter sieve, and the total nitrogen was 0.862 per cent.

Solubility of the nitrogen compounds of the soil.

Solvent.	Nitrogen in solution, calculated to original soil.
	Per cent.
Distilled water, 30° C. 1 hour	0.005
Distilled water, 100° C. 1 hour	.022
Distilled water, 125° C. 3 hours	.050
95 per cent alcohol, 30° C	None.
12 per cent hydrochloric acid, 30° C. 1 hour	.002
12 per cent hydrochloric acid, 100° C. 7 hours	.623
5 per cent caustic potash, 100° C. 1 hour	.728
Acid pepsin, 40° C. 1 hour	.076
Cuprichydrate, 100° C	.011
2 per cent permanganate of potash, 100° C. ½ hour	.516

From these figures and other observations which have been made, the conclusion is warranted that the nitrogenous bodies in the soil are extremely insoluble in common solvents at the ordinary temperature, with the exception of dilute alkalis, as in the determination of humus. Acids and oxidizing agents at boiling temperature render a large portion soluble, this solubility being evidently due to change in constitution.

Ammonia.—The soil on distillation with excess of magnesia gave nitrogen as ammonia 0.007. Using milk of lime instead of magnesia and distilling in a current of steam, the nitrogen obtained as ammonia was 0.035 and on distillation with direct heat 0.053. Distillation with 1.5 per cent caustic soda gave nitrogen as ammonia 0.154. It is seen from these figures that only a small portion of the nitrogen in the soil can be present as ammonium compounds, but a large amount is readily split off as ammonia by alkalis at an elevated temperature.

Dry or destructive distillation of the soil gives an alkaline distillate containing ammonia. The alkalinity of this distillate was found to be equivalent to nitrogen as ammonia 0.168, the total nitrogen in the distillate being 0.145. In addition to ammonia this distillate contains pyridin or some of its homologues, and a portion of the alkalinity is due to these bodies. This seems to indicate the presence of some pyridin ring compound in the soil.

DECOMPOSITION PRODUCTS.

Much of our rather meager knowledge of the complex protein molecule is due to the study of its decomposition products. When the protein molecule is dissociated, whether the means be chemical in the laboratory or the agency of ferments in decay, it splits along certain lines of cleavage and bodies are obtained which have been designated primary dissociation products. The establishment of the constitution

of these bodies has thrown some light on the constitution of the parent body. The reagent most commonly used in the laboratory in bringing about this dissociation has been boiling dilute acids. The literature of this subject is now quite voluminous and dates from 1818, when Proust[a] discovered leucin in cheese. A good general account of the subject is given by Kossel and Kutscher.[b]

With regard to the nitrogen in the soil, it is safe to assume that a large part, if not all, of it has been at some time a component part of the protein molecules in living plants. Whatever may have been the initial stage in the transfer of the free nitrogen of the air to the soil, the stages immediately preceding the final step have no doubt been living protein, dead protein, decaying protein. Such being the case, one might expect some parallel between the compounds resulting from the decay of plant compounds in the soil and the dissociation products obtained in the laboratory. In the soil, however, the study of the process of dissociation is complicated by several factors; the large amounts of mineral matter present may enter into combination with the organic bodies formed; certain organic bodies formed have an absorptive power for others; and, finally, while the process is going on these dissociation products are subject to loss through solution and leaching from the soil or subject to further complex changes by the numerous agents at work in the soil. We would expect, then, that the soil would contain plant residues not yet dissociated and such products of dissociation as had resisted leaching, some probably in combination with the mineral matter in the soil, others absorbed, and still others present as secondary products.

With this in mind a method of classifying the dissociation products of protein proposed by Osborne and Harris[c] was applied to the soil. This method, which is a modification of that of Hausmann,[d] is in short at follows:

Boiling the material with dilute acid, removing the excess of acid by evaporation, determination of the nitrogen present as ammonia by distilling with magnesia, determination of the nitrogen in the magnesia precipitate, precipitation of the basic nitrogen in the filtrate by phosphotungstic acid, and the determination of the nonbasic nitrogen by difference. In applying this method to soil 10 grams were boiled under a reflux condenser with 100 cubic centimeters, 12 per cent hydrochloric acid, usually for seven hours, and the insoluble residue boiled for the same time with 100 cubic centimeters sulphuric acid, the process as outlined being carried out with the two solutions separately, the removal of excess of acid by evaporation of course being applied to the hydrochloric-acid solution only.

---

[a] Ann. Chim. et Phys., 10 (1819), p. 40.
[b] Ztschr. Physiol. Chem., 31 (1900), p. 165.
[c] Jour. Amer. Chem. Soc., 25 (1903), p. 323.
[d] Ztschr. Physiol. Chem., 27 (1899), p. 95.

In treating the soil with boiling hydrochloric acid of this strength the amount of nitrogen rendered soluble was found to be increased very little on prolonging the boiling more than two hours. The difference between boiling two hours and fourteen was found to be 0.08 per cent nitrogen, the total amount in solution at the end of fourteen hours being 0.630 per cent. During the first hour of boiling there is much frothing, and if the operation is stopped at this stage a somewhat viscous solution is obtained very difficult to filter. This viscous character of the solution wholly disappears after two hours, and it is evident that the prolonged boiling brings about some change in constitution, and is not merely a separation of organic bodies from combination with the basic elements in the soil.

This method when applied to the soil gave the following figures:

Solubility and forms of nitrogen in acid solutions.

	HCl solution.	H_2SO_4 solution.	Total.
	Per cent.	*Per cent.*	*Per cent.*
Nitrogen in solution	0.623	0.112	0.735
Nitrogen as ammonia	.119	None.	.119
Nitrogen in MgO precipitate	.280	.105	.385
Basic nitrogen	.140	.005	.145
Nonbasic nitrogen	.084	.002	.086

Considering these dissociation products in detail, the following points should be noted. The whole of the ammonia is that obtained from the hydrochloric-acid solution. The ammonia already present in the soil was 0.007, leaving 0.112 split off by the action of boiling acid. Practically all investigators agree that ammonia is one of the primary dissociation products of boiling protein with acids.[a] Determination of ammonia in this method by distilling with magnesia is open to the objection that ammonia may be formed as a secondary product; but neglecting the error due to this, which must be small in any case, we have the following conclusion warranted by the figures obtained. There is present in the soil 0.007 ammonia as the residue of previous dissociation through decay, and if subsequent dissociation in the soil should be of a similar character to that produced by acids in the laboratory there would finally result 0.112 ammonia. Just how far the two methods of dissociation are similar, and how much of the ammonia would remain fixed in the soil and how much lost by leaching or further chemical change, is of course unknown.

The nitrogen in the magnesia precipitate has been by most investigators designated "humin nitrogen." The term humin was first used by Berzelius[b] instead of "ulmin and geine," which had been applied

[a] O. Nasse, Arch. Physiol. [Pflüger], 6 (1872), p. 589; 7 (1873), p. 139; 8 (1874), p. 381. H. Hlasiwetz and J. Habermann, Liebig's Ann. Chem., 169 (1873), p. 150. A. Kossel and F. Kutscher, Ztschr. Physiol. Chem., 31 (1900), p. 165. E. Fischer, Ibid., 33 (1901), p. 151; 33 (1901), p. 177; 35 (1902), p. 70; 36 (1902), p. 462.

[b] Poggendorff's Ann., 44 (1838), p. 375.

to the dark-colored constituents of vegetable mold. Mulder[a] showed that brown or black substances of a similar nature were formed on boiling albumins with strong acids; and later other investigators showed that humin substances were formed in the same way from many other bodies, especially carbohydrates.[b]

When the body acted on contains nitrogen the resulting humin substance also contains nitrogen, and the same is true for iron and sulphur. Schmiedeberg[c] has shown that these humin substances present a great resemblance in properties and chemical composition to the dark pigment in hair and skin. These pigment substances are known as melanins, and he has proposed for the humin substances the name melanoidins. The humin substances or melanoidins occurring naturally as the result of decay or produced by chemical reagents in the laboratory should be distinguished from humus. The term humus, as used in soil chemistry, is simply an empirical term for an alkaline extract of the soil made in a certain way. This extract contains the dark-colored humin substances of the soil, but it also contains other nitrogenous bodies. From the alkaline soil extract known as humus, acids precipitate humin bodies, and on filtering a portion of the nitrogen extracted is found in the acid filtrate.

The melanins, the resemblance between which and the humin bodies has been noted, are the dark-colored pigments found in hair, skin, the choroid coat of the eye, and in certain abnormal tissues, such as sarcoma. They are amorphous bodies, and so far as known do not give any special reactions. They differ in composition according to the source, and agree only in having a high carbon and low hydrogen content. Analyses of many of these have been made, some of which are given below.

Composition of melanins from different sources.

Source of melanin.	C.	H.	N.	S.	Fe.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per ct.*
Sarcoma[a]	55.76	5.95	12.3	8–9	0.06
Hair[b]	52.74	3.33	10.51	3.34	.....
Skin, negro[c]	51.83	3.86	14.01	3.6	.....
Sepia[c]	56.34	3.61	12.34	.52	.....
Melanoidin[d]	66.27	5.49	5.57	.0	.....
Do.[d]	60.34	4.86	8.09	.95	.....

[a] K. A. H. Mörner, Ztschr. Physiol. Chem., 11 (1887), p. 66; 12 (1888), p. 229.
[b] Abel and Davis, Jour. Expt. Med., 1 (1896), p. 361.
[c] M. Nencki and N. Sieber, Arch. Expt. Path. u. Pharmakol., 24 (1887), p. 17.
[d] O. Schmiedeberg, Ibid., 39 (1897), p. 1.

On precipitating the humin substance or melanoidin from a humus extract of the soil made with 5 per cent caustic soda with hydrochloric

[a] The Chemistry of Vegetable and Animal Physiology. Trans. by D. P. H. Fromberg, Edinburgh and London, 1849, p. 153.

[b] L. V. Udránszky, Ztschr. Physiol. Chem., 11 (1887), p. 537; F. Hoppe-Seyler, Ibid., 13 (1889), p. 66; O. Schmiedeberg, Arch. Expt. Path. u. Pharmakol., 39 (1897), p. 1; F. Samuely, Beitr. Chem. Physiol. u. Path., 2 (1902), p. 355.

[c] Arch. Expt. Path. u. Pharmakol., 39 (1897), p. 1.

acid, washing free of acid and drying, there was obtained an almost black body containing 3.16 per cent nitrogen and 18.96 per cent ash. As the humus extract had been passed through a Pasteur filter, the ash constituents were wholly in solution. This ash contained 93 per cent alumina and but a trace of iron. On treating some of the humin substance so obtained with dilute ammonia before drying, a portion was insoluble. The ammoniacal solution on treatment with a slight excess of hydrochloric acid gave a precipitate of humin bodies which on washing and drying was similar in appearance to that first obtained. This body contained 4.9 per cent nitrogen and 8.36 per cent ash.

When the humin substance obtained from a caustic soda extract by precipitation with hydrochloric acid is dissolved in caustic soda and precipitated again with acid, a further quantity of nitrogen is obtained in the acid filtrate. The following figures illustrate this: A humus extract made with 2 per cent caustic soda contained 0.516 nitrogen per cent of soil. On precipitating with hydrochloric acid and washing free of acid there was obtained in the acid filtrate 0.115 per cent nitrogen. A second solution and precipitation gave 0.056 per cent and a third 0.022 per cent nitrogen in the acid filtrate, making a total of 0.193 per cent nitrogen in the humus extract other than in the humin bodies. Although humin bodies from the soil absolutely free of nitrogen have not been obtained, it seems probable that by carrying on the solution and reprecipitation still further this result would be obtained. In any case, the fact that a portion of the nitrogen continues to be extracted by this process indicates that the nitrogen is absorbed rather than in chemical combination in the humin bodies.

In the treatment of pure protein with boiling acids the amount of nitrogen obtained in the magnesia precipitate and classed as humin nitrogen is small; for instance, Osborne and Harris[a] give the following among other figures:

Proportion of nitrogen of proteids precipitated by magnesia.

Protein.	Total nitrogen.	Nitrogen in MgO precipitate.
	Per cent.	*Per cent.*
Wheat globulin	18.39	0.28
Legumin	17.97	.17
Casein	15.62	.21
Gliadin	17.66	.14
Zein	16.13	.16

It is held by some investigators that the formation of humin bodies from protein by this treatment is the result of the action of the acid on some of the primary dissociation products; that is, that they are secondary products.[b] By this method the soil studied gave 0.385

[a] Jour. Amer. Chem. Soc., 25 (1903), p. 348.

[b] L. Langstein, Ztschr. Physiol. Chem., 31 (1900), p. 49.

humin nitrogen in a solution containing 0.735, or 52.3 per cent. The amount insoluble in 12 per cent acids was 0.2, which is probably of humin nature. On the assumption that this is so, the total humin nitrogen is 0.585, or 56.1 per cent. This represents the humin nitrogen in the soil plus that produced by the action of acids. In the chemical analysis of the soil the humus nitrogen was found to be 0.56, or 76 per cent, but, as has already been pointed out, the humus nitrogen includes other nitrogen than that of the humin bodies. Whether the figure 0.585 given above represents approximately the humin nitrogen which would ultimately accumulate in the soil depends on a number of factors, regarding which our information is indefinite. For instance, it is not known how much of the nitrogen insoluble in acids is humin nitrogen, nor to what extent the magnesia precipitate contains other nitrogenous bodies; and very little is known regarding the agents at work in the soil tending toward the destruction of these bodies.

The nitrogen classed as basic and which is precipitated by phosphotungstic acid is, in the case of protein, that of the diamino acids, of which lysin, arginin, and histidin are the most important. Whether any of these or related bodies are included in this classification when applied to soil has not as yet been determined.

The nonbasic nitrogen, which is determined by difference, is, in the case of protein, made up of the monoamino acids, glycocol, alanin, leucin, and aspartic acid being the most important. As in the case of the diamino acids, we know nothing at present as to what bodies are represented in this division when the method is applied to soils.

The results of the application of this method to the soil may be summarized as follows: Boiling with 12 per cent hydrochloric acid, followed by boiling with 12 per cent sulphuric acid, renders soluble 0.735 out of 0.935 nitrogen in the soil. The insoluble portion is probably humin nitrogen; nothing definite is known regarding it. In the solution 16.1 per cent is in the form of ammonia, all in the hydrochloric-acid solution. More than 50 per cent of the nitrogen dissolved is that classed as humin nitrogen, the humin bodies being dark-colored amorphous bodies containing nitrogen and seeming to be related to the dark-colored pigments or melanins occurring in hair, skin, etc. Some of the nitrogen in the magnesia precipitate may not be humin nitrogen as the term is ordinarily understood. It is noteworthy that after treatment with hydrochloric acid more than 92 per cent of the nitrogen dissolved by subsequent treatment with sulphuric acid is included in the humin nitrogen. Of the two remaining classes—basic or diamino and nonbasic or monoamino nitrogen—nothing is known as yet in the application of this method to soil.

While the results from the application of this method are as yet of the most general nature, and very indefinite, it is one which seems to

the writer to promise some light on the constitution of the nitrogenous bodies in the soil. The method has been applied in some of its several modifications to protein by a large number of workers, and most of the decomposition products have been described, both as to composition and constitution, so that in applying it to soil nitrogen one finds a vast amount of information regarding bodies which must be, if not identical, at least closely related to those found in the soil. A study in detail of these bodies included in the several divisions of the classification made by this method is now being made.

ALKALINE SOLUTION.

In treating of the general properties of the soil it was pointed out that treatment with dilute alkalies at the ordinary temperature, as in humus determination, was the only method found of rendering any large proportion of the nitrogenous compounds in the soil soluble without the application of heat, or other treatment, by which solution would be accompanied with more or less decomposition.

Treatment with dilute alkaline solutions results in a dark brown, almost black, solution, the so-called humus extract. From this solution mineral acids precipitate the dark colored humin substances as a flocculent precipitate containing nitrogen. The filtrate from this precipitate is dark red and also contains nitrogen. From this filtrate, on neutralizing with caustic soda, there is thrown down a dirty brown gelatinous precipitate containing nitrogen. When the original extract was made with caustic soda this precipitate contains a large amount of alumina. The filtrate from this precipitate, which is yellow, also contains nitrogen. From the original extract there is thus made a separation into three groups, all containing nitrogen: (1) The humin substances, dark colored amorphous bodies soluble in alkalis, insoluble in water and dilute acids; (2) the dirty colored precipitate, soluble both in acids and alkalis, but insoluble in water, and containing dark colored organic matter, as well as a large proportion of mineral matter; and (3) the neutral yellow filtrate. In addition to containing nitrogen each of these on being dried and heated with lime gives the odor of crude pyridin, so that it is evident a portion of the nitrogen in each is in the pyridin ring form.

The following figures were obtained in making this division. A humus extract made with 2 per cent caustic soda solution contained 0.0399 gram nitrogen per 100 cubic centimeters solution. Making this slightly acid with hydrochloric acid, filtering and washing, the filtrate contained 0.0251 gram nitrogen per 100 cubic centimeters original solution. On neutralizing this acid filtrate with caustic soda, filtering and washing, the precipitate contained 0.0168 gram nitrogen per 100 cubic centimeters original solution. Stated per 100 N. extracted this result is as follows: Division 1, 37 per cent; division 2, 42.1 per cent; division 3, by difference 20.9 per cent.

This solution in cold alkali and the division into three groups each containing nitrogen furnishes a second empirical method of studying the nitrogenous compounds of the soil. While the first method, that of dissociation with boiling acids, can give an insight into the constitution of these compounds only indirectly through their dissociation compounds, the second presents a possibility of studying a portion at least of these compounds in solution unchanged. For this reason this method was taken up first in detail.

PYRIDIN COMPOUNDS IN THE SOIL.

Each of the three groups separated from alkaline solution in addition to containing nitrogen has another property in common, viz, that of giving pyridin or its homologues on heating with lime.

It has already been noted that the soil studied gave on dry distillation some pyridin in the alkaline distillate. The alkalinity of this distillate, which is largely due to ammonia, has varied somewhat according to the manner of distillation. In one distillate pyridin was determined by the method of François,[a] and there was obtained pyridin 0.0773 per cent of the soil, or nitrogen as pyridin 0.0137 per cent of the soil. This method, which depends on the formation of the aurichlorid $C_5H_5NHCl.AuCl_3$ and its insolubility in ether, gives accurate figures with aqueous solutions of pyridin, but how far it is applicable in the presence of the higher homologues of this body, some of which are evidently present in the distillate, is not known. For this reason this figure must be regarded at present as an approximate one only. The chief point in this connection is the formation of pyridin on dry distillation.

Pyridin was first obtained from the oil resulting from the dry distillation of bones.[b] It is also obtained by the dry distillation of bituminous coal, peat, wood, etc. The commercial source at present is coal tar. A number of alkaloids yield pyridin when highly heated, for instance, it occurs in tobacco smoke as a product from nicotine.

With regard to the formation by dry distillation of such substances as coal and peat, some authorities hold that it is due to the reciprocal action of fats and ammonia, the acrolein from the first condensing with the ammonia to form pyridin.[c] This would not apply to the formation of pyridin from alkaloids, which are, for the most part, pyridin ring compounds. Samuely[d] has shown that the melanoidins or humin substances resulting from the dissociation of protein give pyridin on reduction. For this reason there has been a tendency to

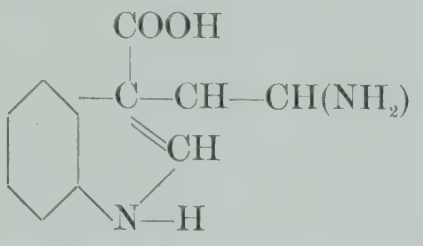
[a] Jour. Pharm. et Chim., 6. ser., 18 (1903), p. 337; Compt. Rend. Acad. Sci. [Paris], 137 (1903), p. 324.

[b] Anderson, Trans. Roy. Soc. Edinb., 20 (1853?), p. 253; abs. in Jour. Prakt. Chem., 54 (1851), p. 36.

[c] Richter, Organic Chemistry, Vol. II, p. 528. Philadelphia, 1902, 3. ed.

[d] Beitr. Chem. Physiol. u. Path., 2 (1902), p. 355.

assume a pyridin nucleus in the protein molecule. Ellinger[a] has, however, suggested for tryptophane, one of the dissociation products of protein, the structural formula



The establishment of this formula would explain the closure of the pyridin ring in protein dissociation products without the necessity of assuming the existence of the pyridin ring as such in the protein molecule. Ellinger states that a genetic relationship exists between tryptophane and pyridin, and quinolin derivatives in plants, such as alkaloids. Hopkins and Cole[b] have shown that tryptophane is readily changed to dark colored humin substances on boiling with acids or even with water.

The chief point of interest at this stage is whether the formation of pyridin on dry distillation is evidence of the presence of a pyridin compound in the soil.

Viewed in the light of our present knowledge and the theories stated above, the formation of pyridin on dry distillation may be due: First, to the interaction of fatty material and bodies yielding ammonia; second, from melanoidins or humin bodies; third, from some vegetable residue known to contain a pyridin nucleus; and, fourth, from the decomposition of the lime salt of a pyridin carboxylic acid.

If the formation of pyridin is explained by the first method, it means that the pyridin ring is a condensation product of distillation and does not exist as such in the soil. This supposition does not seem likely, for although ether extract of the soil was 0.005 per cent, the soil yielded pyridin after extraction as before.

The possible connection between tryptophane and pyridin, and the readiness with which the former is converted into melanoidins, have been noted, and we have in this a possible explanation of the formation of pyridin. However, accepting the theory that the pyridin is formed from the humin bodies, our lack of knowledge of the constitution of these bodies still leaves unsettled the question whether the pyridin exists as such in the soil. It should be noted in this connection that no trace of tryptophane has been found in any of the soil extracts.

The formation of pyridin according to the third method stated above means that some vegetable compound containing a pyridin nucleus had resisted decomposition and existed unchanged in the soil.

---

[a] Ztschr. Physiol. Chem., 43 (1904), p. 325.

[b] Jour. Physiol., 27 (1901), p. 418; 29 (1903), p. 451.

A large number of alkaloids contain a pyridin nucleus, and it is probable that a large number of plants contain compounds of this character which have not been identified or studied. Moreover, the alkaloids are quite resistant to decomposition, and it would not be an unlikely thing to find alkaloids in the vegetable débris making up the organic matter in the soil. In the case of the soil studied no reactions for alkaloids have been obtained in any of the soil extracts made. The only indication of alkaloids was obtained in the distillate resulting from passing steam through soil covered with a 2 per cent solution of caustic potash. From this distillate, which contained a large amount of ammonia, there was obtained a very small amount of a volatile oily substance having the odor of coniin. No reactions for coniin could be obtained, and the amount has been far too small for identification. Its properties so far as determined point to some product of bacterial action related to the ptomaines putrescin and cadaverin.

With regard to the fourth method it is characteristic of a large number of pyridin carboxylic acids that the lime salts of these acids or the acids themselves when heated in contact with an excess of lime give pyridin. This applies also to the carboxylic acids of the homologues of pyridin, the corresponding homologue being obtained. Theoretically this is the simplest explanation of the production of pyridin on dry distillation of the soil. As the total amount of lime in the soil is small and apparently all in combination, this explanation would hold only in the presence of a lime salt of a pyridin carboxylic acid or a similar acid of some homologue of pyridin.

It would seem, then, that the pyridin obtained on dry distillation of the soil is due either to some obscure reaction involving the humin bodies or to the decomposition of the lime salt of some pyridin carboxylic acid.

NEUTRAL SOLUTION.

Returning now to the alkaline solution and the empirical divisions made of it we find that in division 3 we have a neutral solution containing a portion of the nitrogen extracted from the soil. The manner of making the extract and subsequent divisions; treatment with dilute alkalis and acids without the application of heat, is such that it is safe to conclude there has been no change of constitution; or, in other words, that any compound which appeared in the final neutral solution would be the same compound actually present in the soil, the only change being that of combination. A study of this neutral solution offers then the readiest method of arriving at the constitution of some of the nitrogenous bodies in the soil. Working with a solution made with 5 per cent caustic soda and making the division using nitric acid instead of hydrochloric as outlined above the following results were obtained with the neutral filtrate.

On being concentrated to small bulk a small amount of dark flocculent apparently humin substance was precipitated. The filtrate from

this gives a voluminous white precipitate with silver nitrate. This precipitate becomes darker on exposure to light and is soluble in ammonia. On decomposing this precipitate with hydrogen sulphid and concentrating the filtrate from silver sulphid to small bulk crystals were obtained quite soluble in hot water, but difficultly soluble in cold. On repeating this process several times the crystals were obtained almost free from color.

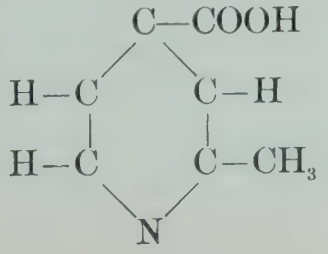
Lead acetate gives with the neutral solution in most cases a slight precipitate, apparently coloring matter. On filtering from this and adding ammonia there is thrown down a heavy yellowish precipitate consisting, of course, in part of basic nitrate. On decomposing this with hydrogen sulphid, neutralizing free nitric acid with ammonia, concentrating to small bulk, adding silver nitrate, and treating the precipitate so obtained as above the same crystalline preparation was obtained. This precipitation with ammoniacal lead acetate and subsequent precipitation with silver nitrate was found to be a readier method of obtaining crystals free from color than direct precipitation as the silver compound.

The crystals prepared in this way, as already stated, are soluble in hot water, little soluble in cold. They are very little soluble in alcohol and insoluble in ether. From solution in hot water on cooling oblique prismatic crystals separate having a very peculiar appearance, giving en masse the impression of being slices or scales and resembling somewhat crystals of benzoic acid. On rapidly cooling a hot, very dilute solution minute crystals, regular in form, are obtained, as shown in Plate III, figure 2.

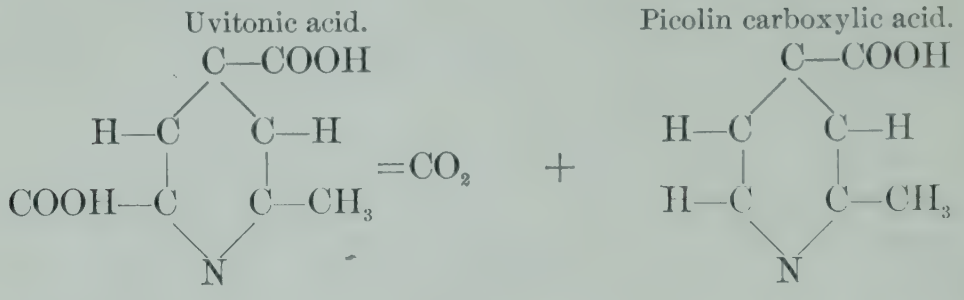
This preparation when heated in an open watch glass sublimes without melting and leaves no residue. The sublimate was found to be the same substance unchanged. Heated in a capillary tube it does not melt at 300° C. The water solution gives no color with ferrous sulphate, and is very faintly acid. The solution neutralized with ammonia gives no precipitate with either barium chlorid, calcium chlorid, cadmium sulphate, or lead acetate. Cupric acetate gives a dark bluish crystalline precipate insoluble in cold water. With hydrochloric acid a compound is formed crystallizing in prisms.

PICOLIN CARBOXYLIC ACID.

The properties of this substance as thus determined point to its being picolin carboxylic acid, or methyl pyridin carboxylic acid. The structural formula of this is:



This acid has been described by Böttinger[a] and was prepared by him by heating uvitonic acid (methyl pyridin dicarboxylic acid) to 274° C. This breaks up as shown below:



The identification of this body has been confirmed by the following determinations. Picolin carboxylic acid crystallizes with one molecule of water of crystallization which it loses at 100° C. A determination of the water of crystallization of the acid from the soil gave 11.34 per cent while that calculated from the formula $C_5H_7NO_2H_2O$ is 11.62 per cent. The hydrochlorid gave Cl 20.50 per cent the calculated Cl for $C_5H_7NO_2HCl$. being 20.46 per cent. Nitrogen in the acid, free of water of crystallization, was found to be 10.02 per cent, that calculated for $C_5H_7NO_2$ is 10.21 per cent. The acid from the soil on oxidation with permanganate of potash yields a body crystallizing in leaflets little soluble in cold water and melting at 239° C. The water solution of this body gives a yellowish orange color with ferrous sulphate. These properties correspond to those of lutidinic acid, one of the pyridin dicarboxylic acids; the picolin carboxylic acid on oxidation yielding lutidinic acid by the oxidation of the methyl group to carboxyl, thus, C_5H_3N, CH_3, $COOH+2O_2=C_5H_3N(COOH)_2+2H_2O$.

This close agreement between the theoretical and determined figures and the properties as determined is sufficient to establish the identity of the substance as picolin carboxylic acid.

The pyridin carboxylic acids include a large number of compounds. Pyridin has five hydrogen atoms replaceable by the carboxyl group. Theoretically there are 19 of these acids possible, all of which are known. All are laboratory products, many of them prepared from alkaloids. In the pyridin ring each of the hydrogen atoms is also replaceable by other groups, e. g. methyl. When this takes place together with replacement of one or more hydrogen atoms by carboxyl we have methyl pyridin carboxylic acid to which group the acid obtained from the soil belongs. Hydrogen atoms in the pyridin ring may also be replaced by other groups so that the possible carboxylic acids is very large. So far none of the pyridin or methyl pyridin carboxylic acids have been found in any plant or natural

[a] Ber. Deut. Chem. Gesell., 14 (1881), p. 67; 17 (1884), p. 92.

product but have all been obtained from other related bodies by chemical means.

There have been six isomeric methyl pyridin carboxylic acids described, picolin carboxylic acid having the CH group in the 2 or α position and the COOH in the 4 or γ position.

In its method of preparation picolin carboxylic acid is of interest in that it can be prepared from its elements. As stated it has been prepared by heating uvitonic acid. This is prepared by the action of ammonia on pyroracemic acid which is obtained by heating racemic acid. This in its turn can be prepared from its elements in a number of ways, ethyl alcohol or carbon monoxid, both of which can be synthesized, being the starting point.

The amount of this acid obtained in a pure form from the soil by the method stated has been small, it being necessary to work with several kilos of soil to obtain enough for the determinations made. No attempt has been made to make quantitative determinations, and the amount obtained has been two to three hundred parts per million of soil, several times the amount of nitrates present under the most favorable conditions.

Picolin carboxylic acid has been obtained from several other Hawaiian soils, including one very heavy clay soil containing but 0.06 per cent nitrogen, so that it would seem not to be confined to highly organic soils.

Mainland soils in quantity have not been available for examination; however, from small samples on hand of soil from eastern States, small quantities of crystals were obtained having the appearance, physical properties, and behavior in solution of those of picolin carboxylic acid.

RELATION OF PYRIDIN COMPOUNDS TO AGRICULTURE.

It is common in Hawaii for farmers to find virgin soil, especially on the uplands, unproductive for the first years of cultivation. In some cases nothing will grow, as might be expected from conditions of soil and climate, and again certain crops will grow and others will not. This condition is generally relieved by cultivation, but in some cases not wholly so. Various explanations have been given for this condition, including ferrous iron, soil acidity, and lack of one or more of the elements necessary as plant food; but in most cases such examinations as are made in chemical laboratories have failed to reveal anything of this nature. For this reason there is in the minds of very many who have attempted to grow crops in Hawaii a confirmed conviction that there is in such cases something poisonous in the soil. Somewhat similar conditions have been observed in limited locations elsewhere. Aside from this, however, there are many facts in regard

to the rotation of crops and the effect produced by certain fertilizing materials, such as stable manure, effects wholly out of proportion to their value as determined by analysis, forcing the conclusion that there exist a whole series of phenomena regarding the relations of plants to the soil that are unexplained and even unmentioned in the current teachings regarding available plant food and fertilization. These general considerations, coupled with exhaustive studies of special soils, have led to the conclusion that in many cases soils do not produce crops for the reason that they contain some body poisonous to the crop grown and not because of lack of plant food.[a] It is not known whether such poisonous bodies are excretions of plant roots or the result of bacterial action on organic compounds in the soil.

It has already been noted that many poisonous alkaloids are pyridin compounds. These alkaloids are plant products and are found in many cases deposited in the seeds. The chemical reactions which precede the secretions of these poisons in the plant are not known, and although they must exist as such in some part of the plant, it is evidently in such form or such place that the life processes of the plant are not interfered with. Experiments indicate that in the germination of seeds containing poisonous alkaloids these nitrogenous compounds are not reassimilated,[b] and so far as the plant is concerned they seem to be either excretions of material for protection or depositions in an insoluble form of material which would injure living protoplasm.

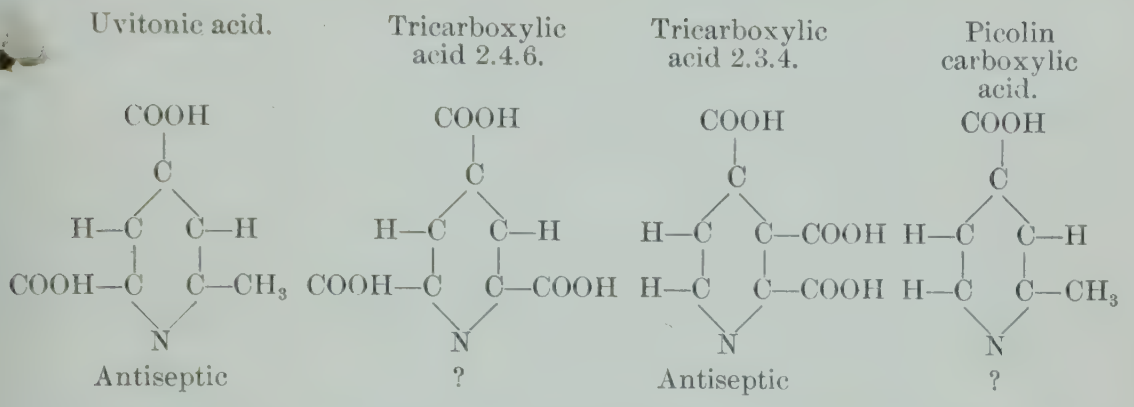
Many fungi can grow on dilute solutions of poisonous alkaloids, and it can not be assumed that because a compound is poisonous to higher animals it will prove so to plants. This can only be determined by experiment.

With regard to picolin carboxylic acid, it is of interest to note its family connections. Uvitonic acid, from which it can be prepared by heating and which differs in composition only by CO_2 and in constitution only by having one COOH group in the place of one H atom, is known to be a strong antiseptic. Further, uvitonic acid on oxidation with alkaline permanganate yields a pyridin tricarboxylic acid. There are five possible isomeric pyridin tricarboxylic acids, the one obtained from uvitonic acid having the carboxyl groups in the positions 2, 4, 6. Another member of this group, having the carboxyls in the positions 2, 3, 4, is also known as an antiseptic, and has been

[a] U. S. Dept. Agr., Bureau of Soils Bul. 28. M. Whitney, U. S. Dept. Agr., Farmers' Bul. 257.

[b] De Vries, Landw. Jahrb., 7 (1878), p. 243. Wotezal, Bot. Jahrb. 41, p. 100. G. Meyer, Bot. Centbl., Beihefte, 6 (1895), p. 61. Heckel, Compt. Rend. Acad. Sci. [Paris], 110 (1890), p. 88.

recommended as such in medicine.[a] The structural relationship between these is shown below:



These facts are suggestive, and it would seem very probable some of the pyridin carboxylic acids might have a detrimental effect on growing plants.

With regard to picolin carboxylic acid, which seems to be a normal constituent of soils, no conclusions have yet been reached either respecting its antiseptic properties or its effects on living plants. Investigations covering these points are being now carried on.

In considering the relation of picolin carboxylic acids to agriculture, there are two points which should be especially considered. First, the solubility of nearly all its salts, although the acid itself is little soluble. Experiments indicate that these soluble salts are readily absorbed by the humin bodies, but to what extent has not yet been determined. The second point is that while it is an acid in constitution in virtue of having a carboxyl group, and forms salts with bases, it at the same time can act as a base and forms compounds with mineral acids by direct addition. All of the pyridin carboxylic acids having but one or two carboxyls have this characteristic, and it is only when the number of carboxyls is increased, as in the penta acid, that the power of uniting with strong acids is lost and the acid character becomes prominent. Picolin carboxylic acid, then, is not one which could be considered a factor in considering soil acidity, or the dissolving, or rendering "available," the mineral matter in the soil.

[a] C. J. Rademaker, Med. Herald, 19 (1887), p. 107.

THE ECONOMIC SEAWEEDS OF HAWAII AND THEIR FOOD VALUE.

By Minnie Reed, M. S.,
Science Teacher, Kamehameha Manual Training Schools, Honolulu, Hawaii.

Hawaii has nearly a thousand miles of coast line; as a consequence the native Hawaiians are skillful and daring fishermen and sailors, as well as splendid swimmers. The Hawaiians, like the Japanese, are fond of almost all the products of the sea, and, like them, prize the seaweed very highly for food. Ancient Hawaiians probably seldom ate a meal without some kind of limu[a] or seaweed, and even to-day no Hawaiian feast is considered quite complete without several varieties served as a relish with meats or poi.[b]

Many tons of these seaweeds are gathered and eaten by the Hawaiians annually, besides large quantities are imported from the Orient and San Francisco for the consumption of both the Japanese and Chinese. The seaweed sold in Honolulu alone amounts annually to thousands of dollars.

Before the coming of the white man to these islands the diet of the poorer Hawaiians was largely poi, fish, and limu. Even poi was scarce in times of war or famine, and then the poorer fishermen contented themselves with only fish and limu. Sometimes for weeks no other vegetable food could be obtained but limu, which can be gathered all the year, except during very severe storms. Sweet potatoes, taro, and bananas could only be grown in the good soil, where there was plenty of rain or sufficient water for irrigation. Many of the fishing villages had no fertile land near them, so these people were compelled to go to the mountain valleys to secure all their food except what they fished from the sea. Until the death of Kamehameha the Great (1819) women suffered the death penalty if they ate bananas, cocoanuts, turtles, pork, or certain fish, so that their diet was even more limited than that of the men. They must have suffered greatly during times of famine and war, when their only food came from the

---

[a] Limu is the Hawaiian name generally applied to all water plants, and is equivalent to our word algæ. They sometimes include various pond weeds, or fresh-water limu, as nitella, chara, etc. Usually limu means either fresh or salt water algæ that are edible.

[b] Poi is a thick paste made from the root of the taro plant (*Colocasia esculentum*), and takes the place of rice or bread in the native diet. It is made by pounding the moistened boiled or steamed roots with water to smooth paste, which is then slightly fermented.

sea. Before the coming of the missionaries there were no fruits except bananas, cocoanuts, and the mountain apple, and none of these were ever abundant, except the mountain apple or ohia,[a] which is plentiful only during July and August in the mountain valleys wherever there is a heavy rainfall.

It was because of this limited food supply, no doubt, that the early Hawaiians learned to use for food almost every living thing, both plant and animal, found along their coasts. Almost every kind of seaweed that could possibly be eaten was used for food by some Hawaiians, while certain of the more attractive algæ were universally used wherever and whenever it was possible to secure them from the sea. The people living in the mountain valleys used, in addition to marine algæ, several kinds of the soft green fresh-water algæ from the streams and ponds. Nothing edible, from tiny shellfish or minnows an inch long to great sharks, escaped the hungry Hawaiian fisherman. Likewise he gathered seaweeds, large and small, and also the fine green algæ of the fresh water to satisfy his hunger for vegetable food. The limu had to take the place of all green vegetables—as onions, lettuce, beets, beans, peas, etc.—as well as fruits, and must have helped very much to vary the monotony of a diet of fish and poi, which were then as now the two staple foods of the native Hawaiians.

There are over seventy distinct species of algæ or limu used for food by the Hawaiians. Of these seventy species not more than forty are in general use. The other thirty or thirty-five are used only by a few people in certain small areas where they are found in limited quantities. There are perhaps a dozen or more common species of algæ, mostly marine, that are termed by the Hawaiians simply limu, or with some descriptive appellation, like limu make, meaning poisonous limu. Each edible limu has its own special appellation besides the generic name limu with which it is combined either as a descriptive adjective or as a suffix.

The following notes and observations have been collected during the last three years from various sources, and from personal study in the markets and along the beaches wherever the limu gatherers were at work collecting or preparing algæ for food. In addition to this, much information has been secured from Hawaiian friends who have very kindly assisted the writer in various ways in collecting both the specimens and data. The writer is especially indebted to Mrs. Emma Metcalfe Nakuina, Mrs. W. L. Bowers, Mrs. Elizabeth Kahanu Gittle, Mrs. Rosina Shaw Leslie, Mrs. Kepoikai, Mr. B. K. Kaiwiaea, Mrs. Deverel, Judge Kahele, and many others for the native names, specimens for study, and descriptions of the methods of preparing them

[a] *Eugenia malaccensis*, in the valleys and mountain slopes in the lowest forest zone. Fruit sweetish, juicy, about size of early June apple, and resembling a red apple, except in flavor.

for food. A number of the pupils of the Kamehameha schools from different islands have, with the aid of their relatives, helped secure specimens of their edible algæ with the native names. They have also furnished many notes on the preparation and preservation of algæ for food. The writer is also very greatly indebted to Dr. W. A. Setchell, of the University of California, for identifying and verifying many specimens, and to R. A. Duncan, food commissioner and chemist of the Territory of Hawaii, for analyzing the edible algæ and for the use of his library.

The following publications have been consulted for tables of analyses and other data: U. S. Dept. Agr., Office of Experiment Stations Circular 46 (rev.), by C. F. Langworthy, Ph. D.; Office of Experiment Stations Bulletins 68, 107, and 159; United States Dispensatory; Analyses of Taro and Poi, report of Dr. E. C. Shorey when food commissioner and chemist of the Territory of Hawaii; Postelsia, the Yearbook of Minnesota Seaside Station, 1901; and Seaweed Industries of Japan and the Utilization of Seaweeds in the United States, by Hugh M. Smith. Bul. [U. S.] Bureau of Fisheries, 24 (1904).

METHODS OF GATHERING LIMUS.

Most of the limu is gathered by native women and children, except that which grows in the deeper or rougher water, far out on the coral reefs, or on exposed rocks, where expert swimming and more strength are required, and also where a boat is usually needed. In such places at least two people are required, and often a party of three or more men and women go together. The women usually gather the limu while the men are fishing and caring for the boat and nets.

The limu gatherers go out at low tide with tin pails, old sacks, and pieces of sharpened iron or an old knife, and scrape the seaweed from the coral or rocks. The seaweed is freed from sand and pebbles and each kind placed in a separate receptacle, if possible. If the limu grows nearer shore in the sand or mud, or floats in near the beach, the women and children wade out, gathering it without any implements, carefully washing out the sand, mud, or small sea animals, and pulling out all inedible limu before placing it in their pails or sacks. They often wade out into the water above the waist, following the tide as it recedes. A few varieties of limu drift ashore, and are simply gathered along the water's edge from the rocks and sand and shaken free from the sand or inedible weeds. The following varieties are often found drifted on the sand or rocks: Limu huna (*Hypnea nidifica*), limu manauea (*Gracilaria coronopifolia*), limu kala (*Sargassum echinocarpum* and *S. cymosum*), and limu lipeepee or limu maneoneo (*Laurencia papillosa*, *L. pinnatifida*, *L. virgata*, *L. obtusata*, and a few other species of Laurencia not yet identified).

Limu uaualoli (*Gymnogongrus vermicularis* var. *americana* and *G. diciplinalis*), limu kohu (*Asparagopsis sanfordiana*), limu aalaula (*Codium muelleri* and *C. tomentosum*), limu lipoa (*Dictyota acutiloba* var. *distorta* and *Haliseris plagiogramma*), and limu lipeepee of several varieties grow far out on the coral reefs or on exposed rocks in the surf. These all have rather tough, firm holdfasts, and a stout sharp knife or chisel is required to loosen them from their supports and strong swimmers to gather them. Those named above are usually gathered by a party in a boat, though sometimes the limu gatherers venture far out on the shallow coral reefs with only their pails or bags and their chisels.

The following varieties of limu grow quite near the tide line along shore, but on exposed black lava rocks in rough water: Limu akiaki (*Ahnfeldtia concinna*), limu loloa (*Gelidium capillacea*, *G. corneum*, *G. filicinum* (?), *G. pulvinatum* (?), *G. latifolium* (?), *G. attenuatum* (?), and *Pterocladia capillacea*), limu uaualoli (*Gymnogongrus disciplinalis*), and limu luau (*Porphyra leucosticta*). These all have very tenacious holdfasts, so generally require a strong, skillful swimmer with a knife or chisel to gather them in large quantities.

Those growing near shore in quiet waters in sand or mud or on small stones are easily gathered with only the bare hands, and usually the older women and children gather these varieties, while the men and the younger strong women gather the varieties growing in the rougher or deeper water. The following are the varieties easily gathered near shore: Limu eleele [a] (*Enteromorpha prolifera*, *E. linza*, *E. intestinalis*, *E. prolifera* var. *tubulosa*, and *E. plumosa*), limu huna (*Hypnea nidifica*), limu manauea (*Gracilaria coronopifolia*), limu pakaeleawaa or limu huluhuluwaena [b] (*Grateloupia filicina*), limu huluilio (*Chætomorpha antennina*, *Ectocarpus* sp. (?), *Centroceras clavulatum*, and *Stigeoclonium amœnum*), limu pahapaha [c] (*Ulva fasciata* and *U. lactuca* var. *rigida*), limu oolu (*Chondria tenuissima* var. *intermedia*), and limu puaki (*Liagora decussata*). There are besides a few other species found only in small quantities, or in certain localities, and only eaten by the Hawaiians in remote districts, or by a small group of families who alone seem to appreciate their flavor. Limu luau (*Porphyra leucosticta*) is one of these which appears in winter or spring after heavy

[a] Limu eleele is applied to a number of slender thread-like green algæ growing near the mouths of streams in brackish water. Most of them are Enteromorphas. On Maui the edible Enteromorphas are called by some natives limu pipilani.

[b] Limu huluhuluwaena is the native name for *Grateloupia filicina*, generally used on the island of Hawaii and in frequent use on Maui and Oahu, while limu pakaeleawaa is the name always used on Kauai and in common use on Molokai, Maui, and Oahu.

[c] Limu pahapaha is applied to several Ulvas on Oahu, Molokai, Maui, and Kauai, while limu pakaiea is the name for the same Ulva on Hawaii.

PLATE IV.

FIG. 1.—USING GLASS-BOTTOMED BOX TO SEARCH FOR LIMU.

FIG. 2.—CLEANING AND PREPARING LIMU.

storms and last for only a few days. It is found on bold exposed rock constantly dashed by waves, so it is difficult and dangerous to collect it, especially as it is extremely slippery and has to be scraped forcibly from the rocks in small bunches while the collector clings to his support and avoids the heavy waves. He must be sure-footed, quick, and a strong swimmer, if he collect limu luau. Limu eleele must always be floated or dipped out of the water into pails, because it always grows at the mouth of streams in the quiet brackish water, so is full of silt or sand. This is partly washed out as the limu is scraped or floated out with the hands into the pails. This limu is very fine and slippery, like hair, so it must be handled in a different manner from other algæ, and requires much more care to remove the sand, the small, clinging mollusks, and crustaceans.

Occasionally you will see a limu gatherer out on the reef, in water almost to her waist, looking very intently through a square glass-bottomed box, and now and then probing the depths with a sharpened iron rod. The iron rod is used to loosen certain mollusks, limu uaualoli, limu lipoa, limu maneoneo, and also to kill eels and octopi, all of which are highly prized for food. The boxes or square frames with a glass bottom have been recently introduced by the Italian fishermen, and are not in general use even near Honolulu. In Plate IV, figure 1, will be seen a limu gatherer looking through the glass box, probing with the iron bar, with a large bag suspended from her neck, into which she thrusts her limu, mollusks, or squid.[a]

At low tides, when the water recedes, wherever there are flats or shallow coral reefs and quiet water, one can see many natives with bags and old knives wading far out gathering limu and other sea edibles, as mollusks, squid, sea urchins, and sea cucumbers or bêche de mer.

NATIVE METHODS OF PREPARING AND SERVING LIMUS FOR FOOD.

Immediately after gathering the limu it is very carefully washed, either in salt or fresh water, to remove all sand, mud, or clinging mollusks and crustaceans. The Hawaiian women are most particular about this cleaning process, so wash the seaweed through many waters, and look it over very carefully to remove every particle of grit or inedible limu that often becomes entangled with the edible varieties. (See limu cleaning in Plate IV, figure 2.)

A few varieties of limu can not be washed in fresh water without injuring the flavor and causing a very rapid decay, so that in a few hours it is entirely unfit for food. The following are the very perishable varieties that must be cleaned in salt water and eaten soon after

[a] The term "squid" is universally applied to the common octopus, *Octopus octopodia*.

preparation: Limu oolu, limu lipeepee, limu lepeahina (*Halymenia formosa*), limu moopuna-ka-lipoa (*Griffithsia* sp.?), and probably a few others not in general use.

After cleaning, the seaweed is always salted and usually broken, pounded, or chopped into small pieces, and usually it is eaten uncooked as a relish with poi, meats, or fish. Raw fish is never eaten without limu or some other relish, such as raw tomatoes, chili peppers, or onions.

The Hawaiians in the ancient times seldom cooked their limu, though it was occasionally placed in the imu or earthen pit with pig or dog and roasted or steamed. This was done when there was a famine or war and taro and sweet potatoes were scarce. Limu akiaki, limu huna, limu manauea, and limu uaualoli were all sometimes cooked in this way as a substitute for taro and sweet potatoes.

The Hawaiians of to-day do far more cooking than formerly, because they are not hampered for cooking utensils as their ancestors, who had no vessels that could be set over the fire. Water could only be heated by putting in hot stones, and boiling or stewing was almost impossible. Their only method of cooking meats or fish was in the primitive imu, or pit lined with stones and heated with a big fire. This when well heated was lined with banana and ti[a] leaves, then pigs, dogs, fish, taro, or sweet potatoes were placed on the ti leaves, covered well with ti and banana leaves, while over this was heaped earth. This was allowed to steam twelve hours or more before serving. Usually hot stones were placed in the pig to hurry the cooking, or if the pig was large it was cut into small pieces for each individual. These small pieces with a roll of taro leaves or some gelatinous limu were placed in ti leaves and tied in bundles, which were placed in the pit and roasted as described above. The limu when steamed in this way with meats becomes gelatinous and is flavored with the meat juices. It is considered very delicious by the natives, who always eat it with the roasted meat and sweet potatoes.

Very few poor Hawaiians have stoves or ovens, so that all their baking or roasting is still done in the primitive way. Their cooking is done over a fire in an old coal-oil tin out of doors, hence must be very simple. Meat is usually boiled or stewed in small quantities with taro leaves or limu. Whenever any Hawaiian gives a large dinner the pig and fish are roasted in the imu as in olden days. The following limus are often cooked with boiled meats or put into soups or gravies for thickening and flavoring, as well as with roast pig in the imu: Limu akiaki, limu uaualoli, limu loloa, limu lipeepee, limu

[a] *Cordyline terminalis*, found on the mountain sides on the edges of the forest. The leaves are used instead of paper for wrappers for food, and for plates, etc. The root is roasted and eaten and is also fermented into a kind of strong drink like rum.

kohu, limu lipoa, limu eleele, limu pahapaha, limu huna, limu manauea, limu aalaula, and limu kala. The tougher, more cartilaginous ones are boiled long enough for the gelatin to be softened or dissolved, as limu akiaki, limu huna, limu manauea, limu uaualoli, limu loloa, and limu lipeepee, while the others are only dropped into the hot soup or gravy just as it is about to be served.

Limu huna is especially prized for boiling with squid or octopus, though limu manauea and limu akiaki are often used as substitutes. These limus, when boiled with squid, produce a jelly of which the Hawaiians are very fond. Limu manauea is considered by native cooks especially fine when boiled with chicken, as it thickens the broth. Sometimes grated cocoanut and cocoanut milk are added to the chicken, forming a very delicious fricasse, which the writer has tested with very great appreciation. The writer has tried nearly all of these gelatinous limus with boiled beef and in beef or other soups, and finds them excellent. They are particularly palatable in vegetable soups, and are probably equally good in chicken or mutton broth, where the limu would make an excellent substitute for tapioca or sago, so often used by American cooks. Limu eleele, being a general favorite and so widely distributed, forms a part of every native feast. After being thoroughly soaked and washed in fresh water it is salted slightly and served uncooked, with poi and fish or meats. It is sometimes put into hot gravy or broth and in meat stews just before being served. It may be kept with a little salt about a week. Some natives allow it to pass through what they call a ripening process, which is as follows: The limu is soaked twenty-four hours or more in fresh water after being cleaned, when it begins to change color, becomes yellowish, slimy, and decomposes somewhat, developing a very rank odor. It is then said to be ripe and ready to eat. When sold in the market it is usually freshly prepared the day before, so is generally eaten without ripening or decomposing.

Limu aalaula, Limu kala, limu moopuna-ka-lipoa, and sometimes limu pahapaha pass through very much this same process of ripening before they are served by some of the Hawaiians in certain localities. Limu kala when ripened in this way is separated from the stems and floats, as only the leaves are eaten. Limu kala is more often eaten fresh and without any preparation whatever. Just as it is taken from the sea it is broken into convenient pieces and serves as a relish with raw fish or squid, which are frequently eaten on the beach as soon as they are taken out of the water and almost before they are dead.

The edible fresh-water algæ are often subjected to the ripening process described above. There are a number of these fine green algæ much alike in appearance called limu palawai, or lipalawai, limu nehe, and limu haulelani, which are usually found in the cool, swift mountain streams or pools. They are all the green threadlike forms of *Cladoph-*

ora nitida, *Spirogyra* sp. (?), *Hydrodictyon reticulatum*, *Pithophora affinis*, *P. polymorpha*, *Stigeoclonium amoenum*, *S.* sp. (?), and other species unidentified, probably Spirogyra and Cladophora. These fresh-water algæ are sometimes taken fresh from the stream and eaten with fresh-water shrimps or opai and a little salt. These fresh-water limus are also occasionally cooked with pig in the imu, or put into the gravy. Most of the fresh-water algæ are eaten by the natives living in the mountain valleys, as the people on the beach seem to prefer their own more accessible seaweeds.

There is a flowering plant found in fresh-water ponds that is eaten by the Hawaiians with great relish, especially with raw opai. This flowering plant (*Naias major*) is called limu kala-wai because it resembles slightly the limu kala from the sea. It is eaten raw with a little salt, much as water cress. It is considered particularly appetizing with raw fresh-water shrimps, opai, or crabs. It is often sold in the market during February and March, when it seems to be most abundant.

Limu lipoa is very often pounded and mixed with other seaweeds to give them its peculiar penetrating, spicy flavor and odor. It is frequently served with meats or put into the gravy or stews to give to them a peppery flavor, of which the Hawaiians are very fond. All Hawaiians like the odor and flavor of this alga, especially with raw fish. It is considered particularly delicious with raw flying fish, if simply broken and salted slightly. This seaweed has a very agreeable spicy taste and odor, and undoubtedly takes the place of sage and pepper in Hawaiian foods.

Limu kohu is always pounded well as it is being cleaned to free it from adhering bits of coral, and also so that it may be soaked more thoroughly to remove the disagreeable bitter flavor. It is soaked twenty-four hours or more in fresh water, to remove the bitter iodin flavor. It is then salted ready to be served as a relish or salad with meats, fish, and poi, or it is mixed with other seaweeds and put into hot gravy and meat stews, just as many other limus are eaten. Limu kohu has a rather pleasant flavor, though it is slightly bitter even after soaking twenty-four hours. It is always found in the market made into balls about the size of a large baseball and heaped upon large plates. It sells at 25 cents per ball and is always in great demand.

A very delicious condiment called inomona is made of the roasted kernel of the kukui[a] nut pounded fine with salt. Many Hawaiians also add a bit of chopped chili pepper and some limu, usually limu kohu, which is pounded very fine and then thoroughly mixed with the

[a] The kukui tree or candlenut (*Aleurites mollucana*) grows abundantly in our mountain valleys and mountain sides, bearing oily nuts, which were strung on grass and burned for torches or candles in ancient times. The oil was extracted and burned in stone lamps. The nuts are edible if roasted.

pounded kukui nuts and salt. This will keep for months in glass jars, and is excellent with bread and butter or cold meats. It resembles Russian caviare in flavor, especially when eaten with bread and butter. The Hawaiians serve this with poi, raw or cooked fish, or roast meats as a relish or condiment. Other limus as limu lipeepee or limu manauea are also sometimes used in making inomona, and if chili peppers can not be obtained, the large green peppers are cooked in ti leaves, then pounded and used instead. The dried gills of the squid roasted in ti leaves are also added by some Hawaiians.

Limu luau or limu lipahee, as it is called in Hawaii (*Porphyra laciniata*), is prepared by washing in the usual way in fresh water. It is then salted a little and put into clear water, where it becomes slippery and colors the water a lovely violet color. Sometimes opihi, a kind of limpet or mollusk, is put in with the limu and salt and water and placed in bottles or jars. This is used as needed, for it keeps many weeks when placed in the weak brine with the limpets. The tender tips of limu pahapaha are sometimes prepared by rubbing and crushing between the fingers, and then it is mixed with small mollusks of a special kind and salt. The finely pounded limu uauaioli is sometimes mixed with salt and small limpets in very much the same way.

The soft parts, particularly the eggs and sperm, of several kinds of sea urchins are salted and mixed with limu uauaioli, limu kohu, or other pounded limus, and this mixture is served and always eaten raw for a relish or entré. In the same way loli (several species of holothurians, as sea cucumbers, bêche de mer, and others) are cut into small pieces and mixed with pounded limu, salt, and sometimes a little chili pepper is added and then served uncooked.

Limu lipahapaha is sometimes boiled with squid, just as limu huna, and forms a gelatinous mass when cold. Limu ekahakaha is sometimes simply pounded and mixed with limpets and sometimes it is cooked with the limpets and seasoned with chili peppers and salt.

Limu aalaula is often pounded very fine and mixed with pounded salted squid, while chili peppers may also be added if preferred. It is also sometimes pounded with other seaweeds to be eaten with poi and fish or meats.

Limu kala is sometimes broken into small pieces and soaked in fresh water until it turns dark and soft, then stuffed into salmon before it is roasted, or it is chopped with fish heads and salt. Again it is sometimes ripened by putting in water with a few mollusks called leho, salted slightly, and allowed to stand several days before eating. Limu kala is more often than any other limu eaten on the beach, without any preparation other than rinsing off the sand and breaking into convenient pieces for eating with raw fish or squid. It is also sometimes put into meat gravies or stews just as it is served.

Limus when eaten raw and crisp with a little salt, or with chopped

chili peppers added, are very pleasant appetizers with meats or fish. The writer thinks that the Americans and Europeans would find them more palatable with the addition of vinegar or lemon and pepper, or possibly an oil dressing. They serve much the same purpose in the Hawaiian diet as our salads, and certain varieties certainly have a very pleasant saline flavor and crispness.

Sometimes various shellfish, as crabs, shrimps, small mollusks, and holothurians or sea cucumbers, are chopped into small pieces and then mixed with the pounded limu and salt and often bits of chili pepper are added to the mixture. This is served with poi, meats, or fish.

Certain seaweeds are always used with certain kinds of fish or mollusks, because their peculiar flavors are considered best when blended together. Shellfish and mollusks are usually eaten raw, and that is probably why chili peppers are usually added, just as with raw fish, to sharpen the flavor, which alone is rather insipid.

THE MOST POPULAR VARIETIES OF LIMUS.

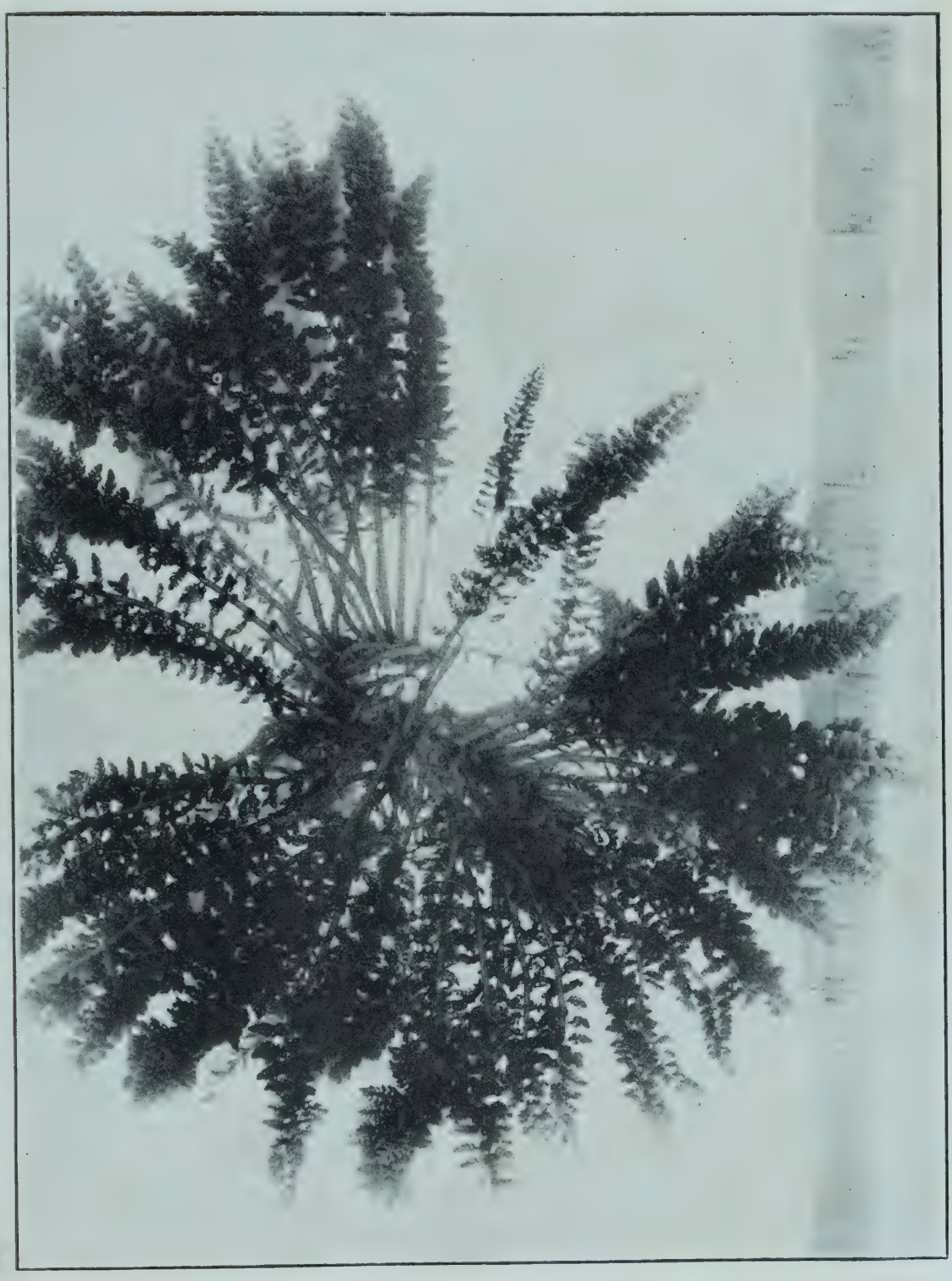
The three limus which are most popular and in the most general use by natives on all the islands are limu eleele, limu kohu (Pl. V), and limu lipoa. None of the other limus are so widely distributed on all the islands nor found in sufficient quantities to be in such general use and favor, except limu pahapaha and limu kala. Neither of these is popular with many Hawaiians, so they are used but little, even though abundant on all the islands.

Next in favor are limu manauea (Pl. VI, fig. 1), limu huna (Pl. VI, fig. 2), and limu pakaeleawaa (Pl. VII, fig. 1), though the latter is native only on the islands of Hawaii and Maui. It was transplanted by certain chiefs to a few places on Oahu and Molokai. The writer was unable to find any specimens of this limu on Kauai or Niihau when collecting on these islands during the summer of 1905, yet several natives insisted that it occurred in Kauai.

Limu luau is considered a great delicacy in the few localities where it occurs, but it lasts so short a season, is so scarce, and so difficult to get that it is not very widely known. Only on northern Kauai, northern Maui, and northern Hawaii is it in use or in great favor, as it does not occur in other places, except a few scattered plants on Molokai and Oahu.

METHODS OF PRESERVING SEAWEEDS.

The Hawaiians usually preserve their seaweed, if only to be kept a few days or a week, by simply salting and tying closely in several layers of ti leaves and placing in a shady place. The ti leaves keep the seaweed from drying and also keep it crisp. The pounded seaweed is often stored in calabashes or glass jars after it is salted or put into weak brine.



LIMU KOHU (ASPARAGOPSIS SANFORDIANA).

FIG. 1.—LIMU MANAUEA (GRACILARIA CORONOPIFOLIA).

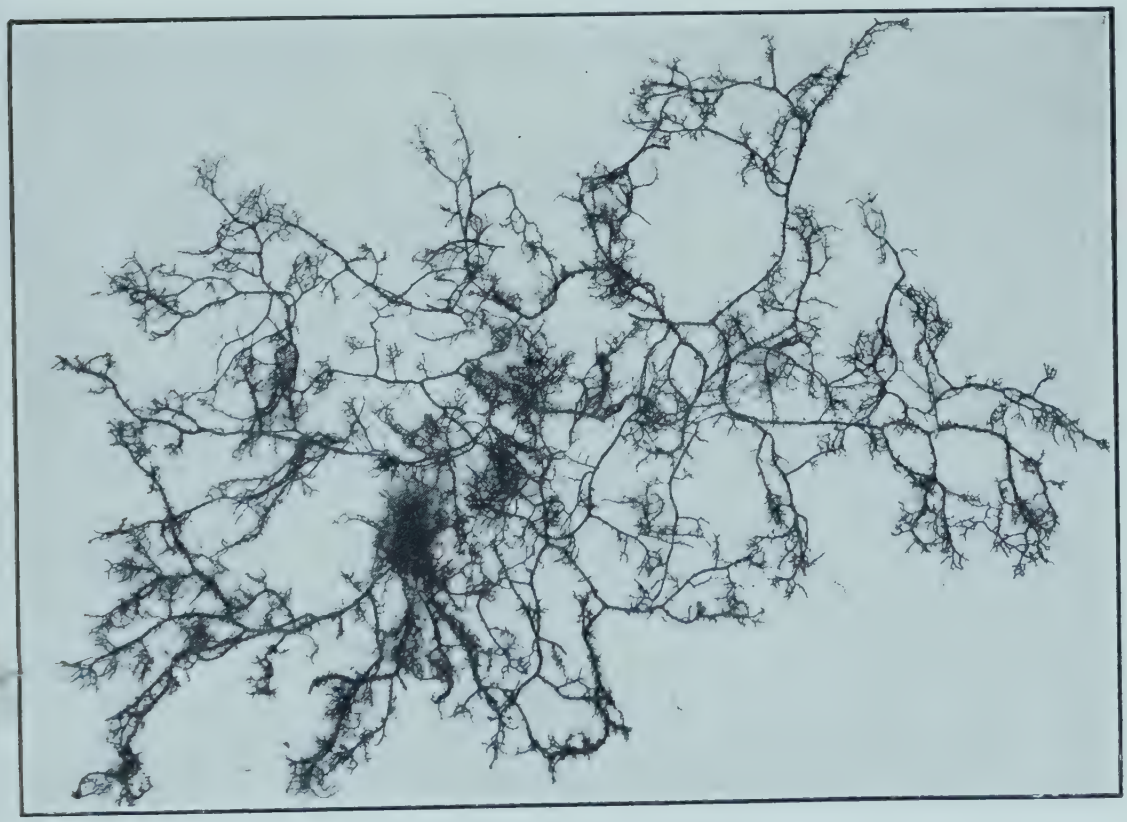


FIG. 2.—LIMU HUNA (HYPNEA SP.).

FIG. 1.—LIMU PAKAELEAWAA (GRATELOUPIA FILICINA).

FIG. 2.—LIMU AKIAKI (AHNFELDTIA CONCINNA).

Limu kohu, limu pakaeleawaa, limu liopa, and limu luau will keep many months, or even a year, when thus preserved. Limu lipoa is not usually kept very long, not more than a few weeks. Most all the other limus in common use are only kept from one or two days to a week, depending upon the weather and the locality. If limu is placed on ice it keeps considerably longer.

Limu pahapaha and limu pakaeleawaa are occasionally kept indefinitely by simply drying without washing off the sea water. Hawaiians very seldom use this method of preserving the limu, as they seem to think that it would be spoiled if allowed to dry. But few Hawaiians seem to know that almost all the seaweeds on the Hawaiian coast can be dried without any perceptible injury either to color, flavor, or texture. The writer has tried almost every species of Hawaiian seaweeds, and with two or three exceptions it was impossible to tell the dried specimens from the fresh if they were first soaked an hour or two in salt water. If fresh water is used for soaking or washing seaweeds it often removes the coloring matter either of the fresh or dried limu. Therefore it is best to add as much salt as is found in normal sea water when washing or preparing seaweeds, either for food or for specimens.

THE LIMUS MOST ABUNDANT AND EASILY GATHERED.

Perhaps the limus most abundant and widely distributed over all the islands are the various kinds of limu kala, and next, perhaps, are several kinds of limu pahapaha, which are found on all the islands and in considerable quantity. Limu huna and limu manauea are very abundant on the islands of Molokai, Oahu, and Kauai, and especially on the leeward side and where there are low shallow beaches and wide coral reefs. Limu huna is scarce on Maui and not reported from Hawaii at all and was not observed there by the writer when collecting. Limu manauea is less abundant on Hawaii and Maui than on the other islands. Limu akiaki occurs in large quantities on the submerged black lava of Kauai, Oahu, and Hawaii, but is plentiful in a few localities on the other islands. At one time it was tabooed except for the chiefs. Limu loloa is most abundant on the islands of Kauai, Molokai, and Oahu, but is found in considerable quantities on the other islands. Most of the limu uaualoli is found chiefly on Maui and Molokai, but is rather scarce on Hawaii. Limu pakaeleawaa is only plentiful on the island of Hawaii on the southeast coast, but is found in limited quantities on Maui, Molokai, and Oahu, having been transplanted to the last two islands. Limu eleele is found in large quantities in the brackish water at the mouth of all the streams that are not too swift.

All the limus mentioned above are easily gathered except limu uaualoli, which grows on the stormy side of the islands on the most

exposed rocks, so unless the weather is very calm it is rather difficult to secure in large quantities.

Limu oolu grows in shallow water near shore or farther out on the shallow sand-covered reefs where the water is quiet, hence is quite easily gathered, but it occurs in rather limited quantity in but a few places.

All the other limus are more difficult to gather and also occur in more limited quantities and in but few localities. This is especially true of limu luau, which is extremely difficult to collect and is very scarce. It grows only on the most exposed and slippery rocks, and disappears in a few days after the stormy weather subsides not to reappear until the next season immediately after the heavy winds. Therefore this much-prized limu is always most difficult to obtain even in very small quantities.

Limu kohu, which is so eagerly sought, grows usually far out on the exposed rocks or on coral reefs, where the breakers dash, so is rather difficult to get even in quiet weather and impossible in heavy storms. Occasionally, however, it grows on reefs less exposed and more accessible.

Limu lipoa is limited to certain localities, and occurs in rather small quantities. It grows in rather deep water, so usually can be gathered only by diving or swimming. It is found in small quantities on all these islands, and is a general favorite.

Limu huna and limu manauea are often drifted upon the beach by the heavy winds or high tides, and may be very easily gathered in boat loads by wading along the shallows at low tide and gathering up the drift on the shore and at the water's edge. It is especially abundant where there are very wide coral reefs under shallow water and a sandy bottom. There are tons and tons of these two limus on the south coast of Molokai, south and east Kauai, and almost all around Oahu, except off Kaena Point and in the harbor, where the water is too deep or muddy for seaweeds to thrive. Wherever there are shallows or reefs off Maui it is also plentiful, though not in such large quantities as the other islands mentioned, because of a less favorable coast.

Limu manauea and limu huna are most abundant in early spring and during the summer months, though both are found in considerable quantities all the year, as would naturally be expected in a tropical region.

Limu loloa can be secured in large quantities all the year round on Molokai, Oahu, Kauai, and Maui, but is not so abundant on Hawaii. It grows on the great lava rocks exposed to waves, so in heavy storms it is difficult to secure.

Limu akiaki (Pl. VII, fig. 2) may be obtained by boat loads all the year, if not too stormy, as it also grows on the great black lava rocks

exposed usually to heavy surf. Sometimes it grows in quiet coves or behind the great lava rocks alongshore in less exposed places, but never in shallow water.

NATIVE METHODS OF CULTIVATING LIMUS.

The writer was much surprised to learn that a rude kind of cultivation of the much-prized limu kohu was practiced at Moloaa, on Kauai. Here limu kohu grows very luxuriantly over the entire reef, and is the finest in color and flavor found on this group of islands.

There is a small cove just beyond Moloaa Bay to the northward, which is partly protected from the heavy trade winds and southerly storms by bold, rocky bluffs or headlands. The coral reef extends from the shore out perhaps a half mile and beyond the headlands, so that the whole cove has rather shallow water. The coral rock, the usual haunt of the limu kohu, is in this place somewhat protected from storms, so the natives can gather this limu almost any time of the year, when the tide is low, without danger from heavy breakers.

The Hawaiians living at Moloaa gather limu kohu for the Honolulu market regularly, making a nice little income from its sale, as they furnish the larger share of the supply. It is here that these limu gatherers have attempted to increase their sales by caring for their seaweed to the extent of weeding out all the other algæ, and thus, no doubt, increasing the quality and quantity of limu kohu, which here is so much finer and more luxuriant than in any other place. This is the only place of which the writer has heard where the limu is actually weeded and cared for as a garden. There are, however, several places where a certain favorite limu has been transplanted from other islands and guarded carefully until it could get established. Limu pakaeleawaa was transplanted from Hawaii to Molokai by an old chief, who planted it on the inner edge of his fish pond, where it is now growing luxuriantly. This same limu has also been transplanted to the beach in front of the residence of ex-Queen Liliuokalani, near Diamond Head, and also in front of her Waikiki place. It is thriving in both places, so the writer has been told. This last summer, when collecting on the north side of Oahu, in Kaneohe Bay, the writer was much surprised to find limu pakaeleawaa growing luxuriantly on the rocks near shore. The native fishermen said that it had been planted there many years before by a chief, who brought it from Hawaii. In all these instances there is an attempt to aid nature, and so a crude kind of limu culture is practiced in Hawaii, though, of course, it is not so extensive or systematic as that in Japan. There may have been more attempts at cultivating or transplanting seaweeds by the natives of the past, for no doubt when a chief moved from one island to another he brought with him his best taro and yam plants for his lands: why not his favorite limus to his fish ponds or beach?

VALUE AND AMOUNT OF NATIVE SEAWEEDS SOLD IN HONOLULU.

It would be rather difficult to tell the exact amount or value of all the seaweed sold each year in Honolulu, but it is possible to make a fairly accurate estimate from the market inspector's report and the Chinese merchants' statements.

The inspector of the fish markets reports the annual sale of 4,800 pounds of limu, valued at about $2,500. It is sold almost exclusively to the Hawaiians or part Hawaiians. Of this total about 2,000 pounds is limu kohu, which is worth about $1,000 at retail. The remaining amount is about two-thirds to three-fourths limu eleele and limu oolu. All the rest are comparatively scarce or not so popular, so are only in the market occasionally during certain seasons of the year. Limu kohu is always in the market, while the other limus are usually found only on Saturdays and the day before holidays.

The following limus are found in the Honolulu fish market, either regularly or at intervals, according to the season or the weather: Limu kohu (*Asparagopsis sanfordiana*), limu eleele (*Enteromorpha prolifera*, *E. flexuosa*, *E. intestinalis*, *E. hopkirkii*, and *E. plumosa*), limu oolu (*Chondria tenuissima*), limu lipeepee or limu maneoneo (*Laurencia papillosa*, *L. pinnatifida*, *L. virgata*, *L. obtusata*), limu manauea (*Gracilaria coronopifolia*), limu lipoa (*Dictyota acutiloba* and *Haliseris plagiogramma*), limu kalawai (*Naias major*), and occasionally limu huna.

Usually these native limus are cleaned, pounded, and salted all ready for serving before they are offered for sale in small plates or saucers. These plates contain from a half pound to a pound of the limu, which sells at from 5 to 25 cents per plate, depending upon the kind. A few varieties like limu lipoa, limu lipeepee, limu manauea, limu huna, and limu kalawai, or fresh-water kala, are sold in loose handfuls, with no preparation except washing off the sand. Every native who buys a fish or a lobster also buys his plate or handful of limu.

Limu kohu is always pounded fine enough to be pressed into balls before it is packed with salt in tins or barrels to be shipped to Honolulu market. When retailed it is made into balls about the size of a large baseball and weighing about a pound. They always sell at 25 cents each, though the balls are smaller in stormy weather when limu kohu is scarce. All these limus are very moist, so they are always tied up neatly in fresh green ti leaves when purchased to prevent the water from leaking out upon the buyer's clothes. The ti leaves also keep the limu fresh and moist and never soak up the water as paper does if tied about something wet.

Nearly all the limu is sold in the market by native women, who have other Hawaiian delicacies, as sea urchins, roasted kukui nuts, crabs, cocoanut pudding, small cubes of raw beef liver, ready to serve with limu, etc.

The amount of limu sold in Honolulu does not of course include nearly all that is actually consumed either on these islands, on Oahu, or even

in Honolulu, as every native family living on or near the beach gets its own supply of algæ fresh from the sea whenever it is desired.

VALUE OF SEAWEEDS IMPORTED BY ORIENTALS INTO HAWAII.

The Japanese and the Chinese of Hawaii use a large quantity of seaweed of various kinds, either prepared in various ways or simply roughly dried. The Orientals seldom use the Hawaiian algæ, as they prefer that cured and prepared in their own country. This is sold only in the Chinese or the Japanese grocery shops.

Most of this imported seaweed comes from Japan and is either kombu or wakame and its various preparations. The Japanese consular report for 1904 says the amount of seaweed sold to Hawaii and to the United States was as follows:

Japanese seaweed sold to Hawaii and the United States, 1904.

Seaweed from Japan.	Weight.	Value.
	Pounds.	
Rough-dried algæ sold to Hawaiian Islands	112,492.73	$1,587.15
Cut or prepared algæ sold to Hawaiian Islands	40,789.77	876.14
Algæ isinglass or kanten sold to Hawaiian Islands	1,751.61	470.72
Algæ isinglass or kanten sold to United States	61,588.31	15,152.30
Total	216,622.42	18,086.31

Nearly all the seaweed preparations described by Hugh M. Smith in his Report of the Japanese Seaweed Industry are sold here in Honolulu by the Japanese grocers to our Japanese population. The different seaweeds and their preparations vary in price from 5 to 30 cents per pound retail. The kanten costs about $1.50 or $1.65 per pound, and it is extremely light for its bulk. Amanori sells in small, thin sheets about 5 by 12 inches for 10 cents per dozen sheets. These sheets are almost as light as paper. Kombu and wakame are sold in the largest quantities, and are boiled to serve with rice, fish, and vegetables.

The Chinese import large quantities of seaweed each year, but there are no consular reports that give the amount or its value; so the following figures are taken from various estimates made by intelligent and responsible Chinese merchants who import this commodity. There are probably 70,000 to 80,000 pounds of seaweed, valued at from $10,000 to $12,000, imported and sold annually by the Chinese grocers of Honolulu.

The prices of these Chinese seaweeds vary from 10 or 15 cents per pound retail for che choy or kum choy (*Porphyra perforata* and *P. umbilicalis*), 7 to 35 cents per pound for toi choy, hoy tai, and san choy (all *Laminaria* sp.), and 75 cents to $1.50 per pound for fat choy (*Nostoc commune flagelliforme*).

The most expensive varieties of seaweed are not sold in large quantities, and of course are purchased only by the most prosperous class of Chinese for feasts and holidays. Fat choy is used in very small quantities, as it is extremely light, swelling greatly in water when

soaked or cooked, so that an ounce makes a considerable bulk when ready to serve. This is also true of most dried seaweeds, and especially of the common kombu, wakame, and che choy.

Che choy (*Porphyra perforata*) is imported from San Francisco and is a substitute for a Chinese alga called tsu choy (probably *Porphyra orbiculata* and *P. tenera*) which is greatly prized by the Chinese. It costs from 75 cents to $1 per pound when imported from China and keeps very poorly, often spoiling soon after its arrival; hence the use of the cheaper che choy from San Francisco. This retails here at 12 to 15 cents per pound, and is said to be almost as good as the Chinese variety. The tsu choy is imported only in small packages for the New Year feasts and sold to a few Chinese epicures.

One Chinese wholesale grocer said that he imported annually two or three tons of che choy, which costs from $600 to $700. He estimated that from 25 to 30 tons of this seaweed was imported yearly from San Francisco, costing from $6,000 to $7,000.

The Chinese use seaweed very much in the same way as the Hawaiians. They cook it in soups, stewed meats, or gravy, and also make it into pickles, preserves, or candies and other sweetmeats.

USE OF LIMUS FOR MEDICINE AND INCANTATIONS.

The writer has been unable to gather much data regarding the medicinal uses of limu, yet the few items collected are of considerable interest. Certain green fresh-water algæ, species of Spirogyra and Cladophora, are said to heal sore eyes if tied on as a poultice. Limu kala is pounded with salt and bound about bruises and cuts to relieve pain. Limu huna is sometimes boiled and the hot infusion given for stomach ache. Limu eleele is dried and put on boils, or it is sometimes used fresh and moist to poultice boils. Limu pahapaha is pounded and put on bruises. Lima luau is pounded to a pulp with salt and the juice is used to moisten bandages on cuts or bruises. Limu eleele and limu palawai are both pounded with salt and tied on cuts and bruises. Limu maneoneo is pounded with salt and the juice is put on cuts or bruises. A species of Centroceras, probably *C. clavulatum*, is pounded with salt and put on bruises and sores. An infusion of this same alga, when cooked, is given for a cathartic.

Limu kala is used by the kahunas or witch doctors in incantations to drive away sickness. The superstitious native when ill gathers limu kala, makes a lei for head or neck, eats some, says a prayer of penitence, promises to do better, then goes into the sea. He must not look back, speak, or beckon to anyone until he takes the limu lei, places it on head or neck, eats a bite of it, then throws the lei back into the sea, still looking out to sea and praying for forgiveness. This ceremony is said to cure if it is faithfully carried out.

It is believed that a most effective love potion is made from limu kalawai, or fresh-water limu kala as it is often called. The lovelorn

maiden says over a magic spell learned from a kahuna, eats the limu kala, then gives some to the one whose love is desired. Straightway he adores her. Limu awikiwiki (*Gymnogongrus reniculatus*) was used also in love-making charms in ancient days, and was probably equally effective.

CHEMICAL ANALYSES AND COMPARATIVE FOOD VALUES OF SEAWEEDS.

The algæ when gathered are very succulent and contain a large amount of water. Considerable of this moisture is lost in the various methods of preparation for the table or for other uses. A number of specimens of Hawaiian algæ were analyzed by Mr. R. A. Duncan, food chemist of Hawaii, in connection with the writer's investigation of this class of plants, and the results are given in the table below, together with some similar analyses which have appeared in earlier publications of the Office of Experiment Stations and elsewhere. All the samples analyzed were air dry.

Composition of edible algæ.

[Air-dry material.]

	Water.	Protein.	Fat.	Carbohydrates.		Ash.
				Sugar, starch, etc.[a]	Crude fiber.	
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Irish moss (*Chondrus crispus*)[b]	18.8	9.4	.....	55.4	2.2	14.2
Fat choy (*Nostoc commune flagelliforme*)[c]	10.58	20.93	1.19	55.73	4.07	7.50
Amanori or che choy (*Porphyra laciniata* or *vulgaris*)[c]	21.85	25.70	.17	37.68		14.60
Do.[d]	15.48	34.35	.65	38.83		10.69
Do.[d]	20.42	36.26	1.21	33.28		8.83
Do.[d]	16.40	35.63	.50	38.13		9.34
Do.[d]	14.58	32.44	.70	43.28		9.00
Do.[e]	13.98	33.75	1.30	41.22		9.75
Kombu or kelp (*Laminaria angustata*)[f]	22.82	5.49	1.52	46.93	4.55	18.69
Kombu or kelp (*Laminaria longissima*)[f]	25.94	6.72	1.73	31.90	6.42	27.29
Kombu or kelp (*Laminaria japonica*)[f]	22.97	4.96	1.59	47.49	5.83	17.16
Kombu or kelp (*Laminaria ochotensis*)[f]	23.99	6.65	.86	42.16	6.03	20.31
Kombu or kelp (*Laminaria religiosa*)[f]	22.75	4.72	.82	42.88	10.20	18.63
Kombu or kelp (*Laminaria fragilis*)[f]	23.10	4.03	.65	40.41	7.15	24.66
Kombu or kelp (*Laminaria* sp.)[e]	23.08	7.11	.87	47.70		21.24
Kombu or kelp (*Arthrothamnus bifidus*)[f]	24.43	5.82	.74	45.58	6.44	16.99
Kanten or seaweed gelatin[g]	22.80	11.71	.....	62.05	.....	3.44
Do.[h]	22.29	6.85	.....	60.32	6.73	3.81
Awo-nori (*Enteromorpha compressa*)[i]	13.60	12.41	52.99		10.58	10.42
Awo-nori (*Enteromorpha linza*)[e]	13.53	19.35	1.73	46.18		19.21
Limu akiaki (*Ahnfeldtia concinna*)[j]	20.16	5.60	.07	54.96	2.66	16.55
Limu pahapaha (*Ulva fasciata* and *U. lactuca*)[j]	18.68	14.87	.04	50.65	.19	15.57
Limu manauea (*Gracilaria coronopifolia*)[j]	12.87	7.91	.05	58.41	2.98	17.78
Arame (*Ecklonia bicyclis*)[k]	13.17	8.99	.....	45.70	7.40	24.74
Do.[e]	18.75	9.58	.46	51.63	9.79	9.79
Hijiki (*Cystophyllum fusiforme*)[k]	16.40	8.42	.....	41.92	17.06	16.20
Do.[e]	15.71	11.37	.49	54.84		17.56
Ulopteryx pinnatifida[e]	18.92	11.61	.31	37.81		31.35
Eckloma bicyclis, partially dried[l]	55.62	4.96	.40	13.60	19.16	6.26
Laminaria, partially dried[l]	52.96	4.11	1.44	29.68	5.25	6.56
Do.[l]	68.26	2.80	.48	19.50	3.29	5.67

[a] Computed by difference except in a few cases which were actually determined.
[b] United States Dispensatory.
[c] U. S. Dept. Agr., Office of Experiment Stations Bul. 68, p. 47.
[d] Imperial Fisheries Bureau of Japan, quoted in Bul. [U. S.] Bureau Fisheries, 24 (1904), p. 160.
[e] Tahara, quoted in U. S. Dept. Agr., Office of Experiment Stations Bul. 159, p. 40.
[f] K. Oshima, quoted in Bul. [U. S.] Bureau Fisheries, 24 (1904), p. 153.
[g] O. Kellner, quoted in Bul. [U. S.] Bureau Fisheries, 24 (1904), p. 141.
[h] Imperial Fisheries Bureau of Japan, quoted in Bul. [U. S.] Bureau Fisheries, 24 (1904), p. 141.
[i] O. Kellner, quoted in Bul. [U. S.] Bureau Fisheries, 24 (1904), p. 164.
[j] R. A. Duncan, food chemist for the Territory of Hawaii.
[k] E. Kinch, quoted in Bul. [U. S.] Bureau Fisheries, 24 (1904), p. 163.
[l] Murai and Kasama, quoted in U. S. Dept. Agr., Office of Experiment Stations Bul. 159, p. 43.

For a proper comparison the fresh algæ should be compared with succulent green foods, like spinach and bananas, or such materials as poi or taro. If the air-dry materials are considered they should be compared with such articles as dried vegetables, crackers, meal, beans, cheese, dried beef, dried fish, etc. In the following table analyses are given of a number of common articles of food, and for comparison three of the more common limus are included, which have been calculated on a uniform water basis of 80 per cent:

Composition of marine algæ compared with other foods.

	Water.	Protein.	Fat.	Carbohydrates.	Ash.	Fuel value per pound.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Calories.*
Limu akiaki (*Ahnfeldtia concinna*)[a]	80.0	1.4	0.0	14.4	4.2	290
Limu pahapaha (*Ulva fasciata* and *U. lactuca*)[a]	80.0	3.7	.0	12.5	3.8	295
Limu manauea (*Gracilaria coronopifolia*)[a]	80.0	1.8	.0	14.1	4.1	290
Wheat bread[b]	35.3	9.2	1.3	53.1	1.1	1,185
Corn meal[b]	12.5	9.2	1.9	75.4	1.0	1,610
Crackers[c]	6.8	10.7	8.8	71.9	1.8	1,905
Taro[d]	67.5	1.9	.2	29.3	1.1	595
Poi[d]	83.0	.3	.6	15.8	.3	325
Potatoes[c]	78.3	2.2	.1	18.4	1.0	385
Sweet potatoes[c]	69.0	1.8	.7	27.4	1.1	570
Beans, Lima, shelled[b]	68.5	7.1	.7	22.0	1.7	555
Beans, dried[b]	12.6	22.5	1.8	59.6	3.5	1,560
Bananas[c]	75.3	1.3	.6	22.0	.8	460
Spinach[b]	92.3	2.1	.3	3.2	2.1	110
Beef, round[c]	67.8	20.9	10.6	.....	1.1	835
Pork, shoulder[c]	51.2	13 3	34.2	.....	.8	1,690
Codfish, salt[c]	53.5	25.4	.3	.....	24.7	410
Beef, dried, salted, and smoked[c]	54.3	30.0	6.5	.4	9.1	840
Mullet[c]	74.9	19.5	4.6	.....	1.2	555
Eggs, hen's[c]	73.7	13.4	10.5	.....	1.0	720
Cheese, full cream[b]	34.2	25.9	33.7	2.4	3.8	1,875
Rice[b]	12.3	8.0	.3	79.0	.4	1,590

[a] Recalculated from figures given in preceding table to uniform water content.
[b] U. S. Dept. Agr., Office of Experiment Stations Circ. 46 (revised).
[c] U. S. Dept. Agr., Office of Experiment Stations Bul. 28 (revised).
[d] E. C. Shorey, Hawaii Experiment Station.

As will be seen by the data in the above tables, carbohydrates constitute the principal nutritive material present in algæ, though they contain considerable quantities of protein and relatively high proportions of ash. So far as can be learned little information is available regarding the character of the nitrogenous material present and the proportions of albumins, which have a high food value as compared with amids or other nitrogenous extractives. As a class the algæ differ very decidedly from the usual food materials in the character of the carbohydrates present, starch being usually replaced by such carbohydrates as mannit and substances which yield on hydrolysis various galactoses, mannose, glucose, pentose, etc.[a]

Judged by chemical composition the air-dry algæ compare favorably with other common food materials, particularly those of vegetable

[a] See summary of data in U. S. Dept. Agr., Office of Experiment Stations Bul. 159, p. 34.

origin. It has been commonly supposed that the Irish moss, so much used in invalid dietetics, and other algæ and food made from them were very thoroughly assimilated, but recent experiments carried on by T. Saiki, at Sheffield Scientific School, Yale University, indicate that this is not the case, at least with respect to the carbohydrate constituents. That they are wholesome and are palatable additions to the diet in regions where they are eaten in quantity is well established, and it seems fair to say that they occupy much the same place in the diet as other common foods, particularly green vegetables. In order that digestion should be normally accomplished foods should be bulky, and in this respect the marine algæ would certainly prove useful. Mineral matters are needed for the formation of bones, teeth, and other tissues, and to fulfill other physiological functions. The algæ are rich in phosphates, chlorids, bromids, iodids, etc., and it seems probable that the mineral matter which they supply must be of importance to the body. As Saiki points out, the algæ gelatins are of much importance in counteracting constipation.

AMOUNT OF GELATIN OR GLUE FOUND IN HAWAIIAN ALGÆ.

The writer made some rather crude experiments to test the various common limus of Hawaii for the amount of gelatin available by ordinary boiling. The most satisfactory results were obtained from the following varieties: Limu huna, limu manauea, limu akiaki, limu kohu, limu loloa, and limu pakaeleawaa. Some others were tried, but they contained very little gelatin or were too strong in flavor to make gelatin for foods. The limu loloa made a very dark gelatin, with a rather strong flavor, so would be more valuable for making mucilage than for gelatin. In making these experiments to extract the gelatin only a small coal-oil stove and a few tin pails were available for boiling the algæ. The seaweed was carefully washed and cleaned, then boiled in clear water from 1 to 3 hours. When it seemed well softened or dissolved, it was passed through a coffee strainer, then through coarse linen doubled. It came through clear, and soon stiffened on exposure to the wind and sun. It was all dried in clear, stiff, crisp sheets on plates in a sunny window. It looked as clear and fine in quality as the best gelatins of the market.

The time of cooking, the amount of gelatin obtained, as well as the quality, varied with the kind of seaweed used. Limu manauea makes the finest, clearest gelatin, and limu akiaki ranks next, limu huna third in quality, while limu pakaeleawaa makes the poorest and smallest quantity. Limu manauea requires the least cooking, and limu huna is next, while limu loloa makes the darkest colored and strongest flavored gelatin. It would make an excellent glue, because it is very sticky, but dries hard as glue should.

Roughly estimated, these seaweeds yield 75 to 80 per cent of their dry weight of gelatin or glue. The writer had no means of carefully weighing the materials to get the exact proportions of seaweed and the glue or gelatin obtained in order to make accurate estimates of their ratios. All the seaweeds occuring on Hawaii in large quantities were tested for gelatin with the above results. Limu uaualoli probably contains a considerable amount of gelatin, but is difficult to gather and can only be secured with some difficulty, and only in very moderate quantities on the north side of Maui, Molokai, Oahu, and Kauai. It is possible that some of the species of Laurencia as limu lipeepee and limu maneoneo might yield some gelatin, but they do not occur in large enough quantities to be of importance in this consideration.

The writer tried using some of this seaweed gelatin as mucilage for pasting on labels and pictures, etc., and found it just as satisfactory as ordinary library paste. It left no shiny mark on the edges. If kept from fermenting by some preservative it would undoubtedly be just as useful as any other mucilage.

HAWAIIAN LIMUS FOR MAKING AGAR AGAR FOR CULTURE MEDIA.

Two small jars of the clearest, best gelatin made from limu manauea and limu huna were taken to the laboratory of Dr. N. A. Cobb, plant pathologist at the Hawaiian Sugar Planters' Experiment Station, to be tested as culture media. He reported them to be quite satisfactory for cultures of various fungus diseases. No doubt if this gelatin were mixed with beef tea, milk, or other suitable foods it would make just as satisfactory a medium for the culture of the bacteria. If we could produce our own agar agar in the United States it would of course save importing it from abroad. Most of the agar agar used in the laboratories of the United States and Europe is made from the algæ of Japan and Ceylon or Java. It is prepared partly in Japan, but the best quality is sent to Germany to be manufactured. We have tons of gelatinous algæ here in Hawaii that would make the best quality of agar agar if we chose to manufacture it ready for the bacteriologist.

FURTHER UTILIZATION OF HAWAIIAN SEAWEEDS FOR FOOD, GELATIN, FARINA, GLUE, AND MUCILAGE.

It is not probable that raw seaweed prepared in the usual Hawaiian style would ever be generally popular with the American or European, who naturally prefers his own salads and relishes to which he is accustomed. Even those having the most pleasant saline flavor and crispness, as limu kohu, limu manauea, limu huna, and limu pahapaha, or limu lipoa, with its peculiar pleasant spiciness have in addition a slight flavor that suggests the sea, to which many people object. It is only

after tasting several times that many people come to really like the marine flavor, common to all raw seaweeds. All the others that the writer has tasted, except those mentioned above, have a much stronger flavor, which is sometimes slightly bitter or suggests iodin, or, again, it is slightly fishy, so that it would not appeal to the average American palate.

Many of the seaweeds, when cooked in soups, gravies, or with meats or made into jellies, are entirely free from this disagreeable or peculiar flavor. If cooked too long, or too large a quantity is used in the soups or jellies, the flavor is apt to be strong, but if used in smaller quantities it is very delicate and pleasant. The writer has carefully tested a number of species, cooking them in a variety of combinations. They seem to be equally palatable when used either fresh or dried. The bleached seaweeds of course make the best appearing jelly and blancmange, and look best in the soups and stews.

The most attractive and delicately flavored coffee, fruit, or other jellies and blancmange was made by the writer from the four gelatinous limus mentioned above. They were equal in every way to jellies made from the best gelatins in the market, and in some ways seemed superior in flavor. The blancmange could not be distinguished from that made with Irish moss farina or with the whole Irish moss.

No doubt these native limus which occur in large quantities could be collected and bleached on the sand or rocks by the natives, and when dry and clean ground into farina or made into gelatin as good as any in the market. The farina made from limu huna, limu manauea, limu akiaki, and limu pakaeleawaa would be excellent for thickening soups, stews, and gravies or puddings in the same way as tapioca, sago, or Irish moss farina. When once the public became acquainted with these preparations without doubt they would become popular. A careful, experienced manufacturer might, it would seem, start a new industry here in Hawaii or on the California coast by utilizing the tons and tons of edible and gelatinous algæ in making gelatin or glue, such as that made in Japan, or farina, as on the coast of New England. There is no reason why Hawaiian species could not be made into as good gelatin and glue as the Japanese or Ceylon algæ. If scientific methods were used in its preparation, and labor was reasonable, we ought to be able to make our algæ as profitable as that of Japan. The many poor Hawaiians living along the beaches, who have no fertile land to cultivate and are only skilled in fishing, swimming, and rowing, could engage in collecting algæ for such a factory. The women and children could help in this industry and all could stay at home together. They would need no tools and no capital or no training for this work. A few simple instructions about cleaning, drying, and bleaching would be sufficient, for the natives know the haunt of every edible limu. A very cheap mill would do for grind-

ing the limu into meal or farina, which would need to be boxed and labeled attractively. The gelatin factory would require more machinery and more capital. It may be that if no factory should be started here our Hawaiians might collect, dry, and bleach their limus and ship them to the coast in bags ready to manufacture, and still make it a profitable industry.

METHODS OF PREPARING JELLIES, BLANCMANGE, SOUPS, ETC.

Coffee jelly and other similar jellies or gelatin desserts are prepared in the same manner as when ordinary gelatin is used, except that the gelatin must first be extracted from the algæ as described above in gelatin preparations. The clear, strained gelatin is then sweetened and flavored with fruit juice, coffee, etc., and placed in a mold to stiffen. It is then served with sweetened and flavored cream, just as with all gelatin jellies. The amount of dried seaweed needed for a pint of jelly varies from 1 to 4 ounces, depending upon the variety of algæ and the stiffness desired in the jelly. The time of cooking also varies with the algæ, and is from one to two hours.

Blancmange is made just as with Irish moss, by cooking the algæ slowly in sweet milk and then straining through a bag. After it is sweetened it is placed in the mold on ice to cool and served with cream sweetened and flavored to taste.

The same limus used in making gelatin are of course used for jellies, blancmange, and in meats and soups. Limu manauea makes the most delicately flavored desserts, though limu huna, limu akiaki, and limu pakaeleawaa are almost as good. Limu kohu is also a pleasant addition to soups or stews if used sparingly, an ounce or two to a kettleful of soup.

COMPARISON OF HAWAIIAN AND JAPANESE SPECIES OF ECONOMIC ALGÆ.

Though Hawaii is a group of recent volcanic islands in mid-ocean, it has a rather varied marine flora along the coasts. There are a hundred and ten or fifteen different species found on these islands. About seventy of these are used for food by some of the Hawaiians. From forty-five to fifty species are in general use for food by most of the Hawaiians on the different islands where they grow.

Japan, being composed of older continental islands, would naturally be expected to have a richer seaweed flora (and probably it has), but Mr. Smith[a] reports a much smaller number of edible seaweeds from those islands than we have in Hawaii. He reports but 35 species that are eaten by the Japanese and 10 others valuable for making glue, gelatin, iodin, fertilizers, etc.

---

[a] H. M. Smith, Seaweed Industries of Japan. Bul. [U. S.] Bureau of Fisheries, 24 (1904).

Not all of these 70 seaweeds eaten by the Hawaiians would be agreeable to the palate of the average American. Probably not more than 8 or 10 out of the 70 would be eaten either by the American or the European, and some of these 10 only occur in limited quantity and only in a few localities. There may, of course, be a few seaweeds here in Hawaii that will prove to be valuable for fertilizers, iodin, or gelatin that have not yet been tested, as the Sargassums.

Probably none of our Hawaiian seaweeds occur in such large quantities as those in Japan, since our coast is much less extensive and many of our islands have bold, precipitous coasts, with very deep water coming up close to the shore on one or two sides. Algæ grow most abundantly in the shallower waters near the coast, and hence the more coral reefs and the more extensive shallows the greater variety and quantity of seaweed. It is, of course, more easily collected on shallow rocky coasts or in coves and bays protected by wide coral reefs, while it is always most plentiful on the coral rocks in these shallows. The tougher, more leathery varieties thrive in the more exposed places and find secure anchorage on the black lava rocks or basalt, as well as on the softer vesiculate lava, which is usually covered with algæ of various kinds, different from that growing on the coral.

While Hawaii is within the tropic zone and probably considerably warmer than Japan, yet she has some of the same species of economic algæ that grow on her coasts. Hawaii produces eight or nine species of Gelidium, while one is the same species (*Gelidium corneum*) which is found so abundantly in Japan and is used in the manufacture of seaweed gelatin. Our species of Gelidium are undoubtedly as gelatinous as the Japanese species, but they are not nearly so plentiful. We also have *Gracilaria confervoides* and *G. coronopifolia*, which are very common on the coasts of Japan. *Gracilaria coronopifolia* is particularly rich in gelatin of the best quality suitable for food, and it also occurs in considerable quantities on all the islands but Hawaii. Our *P. leucosticta* is somewhat similar to the two Porphyras of Japan used in making amanori, but is too rare and too difficult to collect to be of any economic importance here on Hawaii. We also have two edible species of Codium, while Japan has three edible species, but different from ours. Our edible *Grateloupia filicina* is the same as the one used in Japan, though they have two other edible species of Grateloupia. We have two of the three Japanese species of Enteromorpha, besides three or four more edible species. There are two edible species of Gymnogongrus reported from Japan, and we have the same number here, though different species. Of our three edible Ulvas, one is the same, one a variety, and the other is a nearly related species to those found in Japan. We have three or four species of edible

Sargassum, while Japan has only one species of Sargassum, which is used for making iodin.

The Japanese waters are rich in kelps, laminarias, alaria, ecklonia, and other genera of colder waters, but Hawaii has none, nor has she any Chondrus or Gloiopeltis, both of which thrive best in the North Pacific along the coasts of Japan and the United States. The kombu and wakome preparations of Japan are all made from Laminaria and related genera in the kelp group.

It will be seen from the above comparison of genera and species that there is some resemblance between the seaweeds of Japan and Hawaii. Our waters being warmer we naturally have more tropical species and no kelps. Yet quite a number of genera and several species are exactly the same. This would indicate either that these species flourish under widely different temperatures and conditions, or that our water is not so much warmer as the difference of latitude would suggest. Japan has the volcanic rock and the black lava just as we have here, but probably no coral reefs for the algæ.

POSSIBILITY OF CULTIVATING NATIVE, JAPANESE, JAVA, OR CEYLON ALGÆ IN FAVORABLE LOCALITIES ON THE HAWAIIAN OR AMERICAN COAST.

As previously mentioned, the Hawaiians have attempted a rude method of cultivating and transplanting their favorite algæ from one island to another. In moving from island to island the chiefs carried their favorite limu pakaeleawaa from Hawaii to Oahu and to Molokai. It was transplanted carefully along protected beaches or on the inner side of old fish ponds, where it still thrives. The writer found this alga growing only in one place on Molokai, and was told by the natives that it had been planted by a chief in his fish pond. In the same manner it has been planted on Oahu in several places and is thriving. Limu is weeded and cared for on the island of Kauai in order to increase the quantity and quality.

If these crude methods of culture succeed and the natives can establish an alga in a new place successfully, why should not more careful scientific means be very successful if the most desirable varieties of Hawaiian algæ were planted in the most favorable localities on each island?

Perhaps some of the most valuable Japanese algæ could be introduced on the coast of Hawaii and be successfully established. It is possible, too, that certain species of algæ growing on the coasts of Ceylon and Java could also be just as readily transplanted to our islands, because the temperature of the sea is about the same, especially off the coast of Hawaii. Much of the agar-agar of commerce is prepared from the gelatin obtained from seaweeds from Java and Ceylon. This very important requirement of every bacteriological laboratory

might be produced here in Hawaii just as well as in Japan or the East Indies, providing, of course, that our own algæ proves as rich in gelatin or if the Japanese and East Indian seaweeds can be successfully introduced and cultivated here. Some experiments along this line might be very valuable, and they would certainly be very interesting. There are many of our rocks and reefs quite thinly covered or nearly barren of seaweeds, and these might be favorable places to establish new varieties, either from other islands or from Japan and the East Indies.

GENERAL SUMMARY OF THE POSSIBILITIES OF THE SEAWEED INDUSTRY.

If the seaweed industry of Japan is the source of an annual income of $2,000,000, it seems possible that our edible Hawaiian algæ might be available for building up a similar industry of considerable value. The coast line of Hawaii is much less extensive and the amount of seaweed of course very much less, yet there is enough material to supply large factories for making gelatin, glue, farina, or other products. If in addition to the present natural sources of seaweed new localities be successfully planted, either with native, Japanese, or other valuable foreign varieties, a still larger supply of algæ would be available for manufacturing. It would of course take some capital, business judgment, and knowledge of the seaweeds and their manufacture to successfully establish such an industry here or on the coast of the United States. If it is so profitable in Japan, why should it not be profitable here, if properly handled? There are enough Japanese laborers here who know all the methods of preparing algæ to suit the Oriental palate, and these could be employed to do that part of the work in the factory, while the Hawaiians, who love the water and are such expert swimmers and boatmen, could be employed to collect the crude algæ from the sea and bring it to the factory. This would bring employment to the untrained Hawaiians and furnish them with a means of living while they remained at home. The women and children could also help with this work of gathering and drying or bleaching the seaweed for the manufacturer. Some industry of this kind only will bring relief to the mass of the Hawaiians, who are unskilled and undisciplined, so are unable to compete with either the Orientals or Europeans in any branch of labor. The Japanese have driven them out of fishing, at which they are most skillful, because they will not be strenuous or regular enough to furnish the market with fish. Small farming is not practicable for the Hawaiian under present conditions, because it requires more capital, skill, and intelligence than the present Hawaiian possesses. Perhaps in two or three more generations the Hawaiian will acquire the skill, the capital, and the disposition to enter agricultural pursuits gladly. In the meantime poverty and distress are the lot of a large class of landless Hawaiians

living along our coast. If the tons of algæ wasting on our shores could be utilized for gelatin, glue, farina, etc., it would bring some relief to this class, as well as add to the general wealth and prosperity of these islands and to the United States.

The gelatins and glues imported from Japan could be made in the United States just as cheaply, perhaps. Modern methods scientifically applied and machinery would reduce the manufacturing expenses to a minimum. A new source of food for our American people here and in the United States would add also to our national wealth. Further experiments and analyses should be made by the Government to test the nutritive value of our algæ and to find the best methods of securing the greatest amount of gelatin from each variety. Enough has already been done to suggest the future value of our economic algæ if properly utilized.

List of edible algæ of Hawaiian Islands.

Scientific names.	Native names.
Ahnfeldtia concinna J. Agh	Limu akiaki, or limus eleau. [a]
Asparagopsis sanfordiana Harv	Limu kohu, limu lipaakai, [b] limu lipehu, limu koko.
Amansia glomerata Ag	Limu lipepeiao, [c] or limu pepeiao.
Centroceras clavulatum (Agh.), Mont	Limu huluilio, limu hulu, or limu hulu wawae-iole.
Chætomorpha antennina (Bory.), Kuetz	Limu huluilio, [d] limu ilio, or limu manu.
Champia compressa, Harv	Limu oolu.
Chnoospora fastigata pacifica, J. Ag	Limu wawahiwaa, or limu kaupau.
Chondria tenuissima intermedia	Limu oolu.
Chylocladia rigens?	Limu akuila, or limu kihe.
Cladophora nitida, Kuetz	Limu huluilio.
Codium muelleri, Kuetzing	Limu aallaula, [e] limu wawaeiole, or limu wawaimoa.
Codium adhærens (Cabr.), Agh	Limu aalaula.
Codium tomentosum (Huds.), Stackh	Do.
Dictyota acutiloba distorta	Limu alani, [f] or false lipoa.
Dictyota dichotoma	Do.
Ectocarpus indicus?	Limu akaakoa, or limu huluilio.
Ectocarpus sp.?	Do.
Enteromorpha flexuosa (Wulf.), Ag	Limu eleele, or limu pipilani. [g]

[a] Many of the limus have different local names, or each island or adjoining islands has its own name. Limu eleau is used on Maui only.

[b] This limu is usually called limu kohu, except on Maui, Molokai, and Kauai. It is often called limu lipaakai and sometimes limu lipehu. Limu koko is a corruption of kohu.

[c] Different forms of the same name on Hawaii, not widely used, local.

[d] Not widely used; only local on several islands, chiefly on Hawaii and Maui, and this name is applied to several species slightly resembling each other. It means dog's hair.

[e] The last two names found in use in some places on Hawaii, not common.

[f] This is generally called limu alani, but sometimes called false limu lipoa, which it resembles slightly. It is eaten but seldom, as it is bitter.

[g] On Maui it is sometimes called limu pipilani. Limu eleele is the name for most all the Enteromorphas of these islands.

Scientific names.	Native names.
Enteromorpha hopkirkii	Limu eleele, or limu pipilani.[a]
Enteromorpha intestinalis (L.), Link	Do.
Enteromorpha linza (L.), J. Ag	Do.
Enteromorpha plumosa, Kuetzing	Do.
Enteromorpha prolifera tubulosa, Kg	Do.
Enteromorpha prolifera (Muell.), J. Ag	Do.
Gelidium attenuatum?	Limu loloa.
Gelidium corneum var.? (Huds.) Lamour	Do.
Gelidium filicinum?	Limu loloa or limu ekahakaha.
Gelidium latifolium? Born	Limu loloa.
Gelidium micropterum?	Do.[b]
Gelidium pulvinatum?	Do.
Gelidium pusillum?	Do.
Gelidium sp.?	Limu kekuwelu or limu kuwelu.
Gracilaria coronopifolia, J. Ag	Limu manauea.
Grateloupia filicina (Wulf.), Agh	Limu pakaeleawaa or limu[b] huluhuluwaena.
Griffithsia sp.?	L. moopuna, limu ka-lipoa,[c] or limu aupupu.
Gymnogongrus vermicularis americana, J. Ag.	Limu uaualoli.[d] Limu ekahaekaha.
Gymnogongrus diciplinalis (Bory.), J. Ag.	Limu koeleele or koele. Limu awikiwiki. Limu nei.
Haliseris pardalis[e]	Limu lipoa.
Haliseris plagiogramma, Mont	Do.
Halymenia formosa	Limu lepeahina (very rare).
Hydrodictyon reticulatum (Linn.) Lagerh	Limu palawai.
Hypnea nidifica, J. Ag	Limu huna.
Hypnea armata	Do.
Laurencia papillosa (Forst.), Grev	Limu maneoneo[f] or limu lipeepee.
Laurencia pinnatifida (Gmel.), Lamour	L. maneoneo, limu olipeepee, or limu lipee.
Laurencia pinnatifida osmunda	Limu lipeepee or lipee.
Laurencia perforata	Do.
Laurencia obtusata	Do.
Laurencia virgata (Ag.), J. Ag	Do.
Laurencia sp.?	Limu maneoneo or limu lipuupuu.
Liagora decussata	Limu puaki.
Nais major, All	Limu kala-wai.[g]

[a] On Maui it is sometimes called limu pipilani. Limu eleele is the name for most all the Enteromorphas of these islands.

[b] This name is in very general use on Hawaii and Maui, but both names are common on Oahu.

[c] This alga is considered a delicacy on Maui and southern Hawaii, but is very scarce and spoils very soon, so have not been able to secure enough to identify the species.

[d] This limu is usually called limu uaualoli, but the other names are used in certain localities.

[e] This is very rare, only washed ashore occasionally, but resembles the other limu lipoa, hence the name.

[f] The several species of Laurencia are generally called limu maneoneo, if coarse and short, and limu lipeepee if finer and longer. Limu lipee is an abbreviation, while limu lipuupuu has only local use in places on Hawaii and Maui.

[g] This is not an alga, but a flowering plant sold in the market as a limu, probably because it grows in fresh water and resembles the common limu kala from the sea.

Scientific names.	Native names.
Nitophyllum?	Limu haula.[a]
Pithophora affinis? Nordst	Limu palawai[b] or limu lipalawai.
Pithophora polymorpha	Do.
Polyopes?	Limu luau.[c]
Polysiphonia mollis	Limu pualu[d] or limu hawane.
Porphyra leucosticta, Thurst	Limu luau or limu lipahee.[e]
Pterocladia capillacea (Gmel.), Bornet	Limu loloa.[f]
Sargassum echinocarpum, J. Ag	Limu kala.
Sargassum cymosum, Ag	Do.
Sargassum polyphyllum. J. Ag	Do.
Spiridia spinella	Limu hulupuaa.[g]
Spirogyra sp. (probably several)[h]	Limu palawai, limu nehe, and limu polao.
Stigeoclonium amœnum, Kg	Limu huluilio.[i]
Stigeoclonium sp?	Limu palawai or limu lipalawai.
Strebdocladia?	Limu hawane.[h]
Ulva fasciata,[j] Delile	Limu pahapaha or limu palahaloha.
Ulva lactuca rigida (Agh.) Le Jolis	Limu lipahapaha.
Ulva lactuca lacinata (Wulf.) J. Ag	Limu lipalahalaha, limu pakaea.
Valonia utricularis	Limu lipuupuu.

[a] Very rare, only one small specimen obtained from a native on Maui.

[b] Most all the edible green fresh-water algæ are called lipalawai or polawaie, and there are perhaps a half dozen species in the mountain streams that are known by these names.

[c] A single small specimen sent by native on Maui, similar to Porphyra.

[d] Used by but few Hawaiians for food; not popular.

[e] Reported only from two islands and scarce; called limu luau on Kauai and limu lipahu on Hawaii.

[f] This species often called limu loloa on Maui and Kauai.

[g] Not in general use, but eaten in the southern part of Hawaii.

[h] Imperfect and immature specimens, so could not be positively identified.

[i] This grows in brackish water pools by the sea and is eaten by only a few Hawaiians.

[j] These three species seem to be indistinguishable by the natives, and the different islands and localities have various forms of the name, but limu pakaea is only in use on Hawaii.

1085

Issued May 26, 1908.

HAWAII AGRICULTURAL EXPERIMENT STATION,

JARED G. SMITH, SPECIAL AGENT IN CHARGE.

ANNUAL REPORT

OF THE

HAWAII AGRICULTURAL EXPERIMENT STATION

FOR

1907.

UNDER THE SUPERVISION OF

OFFICE OF EXPERIMENT STATIONS,

U. S. DEPARTMENT OF AGRICULTURE.

WASHINGTON:

GOVERNMENT PRINTING OFFICE.

1908.

HAWAII AGRICULTURAL EXPERIMENT STATION.

[Under the supervision of A. C. TRUE, Director of the Office of Experiment Stations, United States Department of Agriculture.]

WALTER H. EVANS, *Chief of Division of Insular Stations, Office of Experiment Stations.*

STATION STAFF.

JARED G. SMITH, *Special Agent in Charge.*
D. L. VAN DINE, *Entomologist.*
J. E. HIGGINS, *Horticulturist.*
ALICE R. THOMPSON, *Assistant Chemist.*
F. G. KRAUSS, *In Charge of Rice Investigations.*
Q. Q. BRADFORD, *Assistant in Rubber Investigations.*

LETTER OF TRANSMITTAL.

HAWAII AGRICULTURAL EXPERIMENT STATION,
Honolulu, Hawaii, February 15, 1908.

SIR: I have the honor to transmit herewith and to recommend for publication the Annual Report of the Hawaii Agricultural Experiment Station for the fiscal year 1907.

Respectfully,

JARED G. SMITH,
Special Agent in Charge.

Dr. A. C. TRUE,
Director Office of Experiment Stations,
U. S. Department of Agriculture, Washington, D. C.

Publication recommended.
A. C. TRUE, *Director.*

Publication authorized.
JAMES WILSON,
Secretary of Agriculture.

CONTENTS.

	Page.
Summary of investigations	9
Chemical investigations	12
Tobacco	13
Entomological investigations	14
Horticultural investigations	16
Rubber	19
Rice	21
Report of the entomologist	25
Introduction	25
Insect injury in Hawaii	26
The sweet-potato weevil (*Cylas formicarius*)	28
The melon fly (*Dacus cucurbitæ*)	30
References to the melon fly (*Dacus cucurbitæ*) in Hawaii	35
Fleas	35
Mosquitoes	38
Bee keeping	39
Foul brood	41
Silk culture	41
A partial list of the injurious insects of Hawaii, part 4	43
Field crops	43
Fruit crops	44
Ornamental plants	46
Forest trees	46
Live stock	47
Stored products	48
Accessions to entomological library relating to Hawaiian entomology	48
Report of the horticulturist	52
Orchard and other fruits	54
The star apple	54
The Anona group	54
The carambola	55
Carica quercifolia	55
The roselle	56
The Natal pineapple	57
Grapes	58
Manila hemp	58
Plantings on the higher elevations of the station land	58
Deciduous plantings	58
Distribution of seeds and plants	59
Horticultural exhibit	59
The need of assistance	60
Report of the assistant chemist	61
Analyses of Hawaiian soils	61
Salt determination in waters and soils	62
Composition of Hawaiian feeding stuffs	63

Page.

Rice investigations—Report of first year's experiments 67
Introduction 67
Plans, objects, and methods of the experiments 68
Notes on variety tests and improvement experiments 69
Methods of cultivation 71
Breeding experiments 72
Summary 75
Fertilizer and culture experiments 76
Introduction 76
Fertilizer experiments 77
Experiment I 78
Experiment II 80
Experiment III 81
Experiment IV 85
Experiment V 86
Experiments VI and VII 87
Culture experiments 88
Influence of age of seedlings at time of transplanting 88
Experiments in broadcasting, drilling, and transplanting rice 89

ILLUSTRATIONS.

PLATES.

Page.

PLATE I. Fig. 1.—Standing water from rice and taro fields where minnows have been successfully introduced. Fig. 2.—Marsh at Waimanalo, on windward side of Oahu, where formerly mosquitoes bred abundantly 38

II. Mulberry seedlings ten months from time of planting 42

III. Fig. 1.—An unnamed Hawaiian seedling orange. Fig. 2.—The star apple (*Chrysophyllum cainito*) 54

IV. Fig. 1.—The sour sop (*Anona muricata*). Fig. 2.—The carambola (*Averrhoa carambola*) 54

V. Fig. 1.—General view of rice plats. Fig. 2.—Upland rice grown under minimum amount of water 70

VI. Fig. 1.—Chinese harrow. Fig. 2.—Transplanting rice seedlings 76

VII. Pot experiments with rice, showing effect of fertilizers 76

VIII. Fig. 1.—Comparisons of Gold Seed and Japan rice. Japan Seed on right, Gold Seed on left. Fig. 2.—Showing method of irrigating fertilizer plats 80

IX. Effect of different fertilizers on yield of Japan Seed paddy and straw 82

TEXT FIGURES.

FIG. 1. The sweet-potato weevil (*Cylas formicarius*) 28

2. Injury to sweet potato by larvæ of the weevil (*Cylas formicarius*) 28

3. Life cycle of the melon fly (*Dacus cucurbitæ*) 33

ANNUAL REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION FOR 1907.

SUMMARY OF INVESTIGATIONS.

By JARED G. SMITH, *Special Agent in Charge.*

The routine office, library, and laboratory work continued throughout the year on much the same lines as during the previous period of the station's existence. Building operations were confined to repairs to the residences on the station, the erection of an additional stable, and the enlargement of the stable capacity of the main barn where the work animals are cared for.

Congress having appropriated $5,000 for the installation of a water system, the plans which had previously been approved by the Secretary of Agriculture were carried out. A corrugated galvanized-iron roof about 200 feet square was constructed on Tantalus, at an elevation of about 1,200 feet. The iron was laid on purlins of 2 by 6 inch northwestern lumber, spiked to the tops of 5-inch split redwood fence posts, which had been set in the ground to a depth of about 2½ feet. This roofing conformed to the slope of the hillside, the purlins being nailed to the posts, so that when the tops of the latter were sawed they formed successive planes. At the lower edge of this roof a 2-foot gutter leads the water into a 30,000-gallon redwood tank. A 1-inch galvanized pipe leads the water from this 30,000-gallon tank down along the ridge into a 60,000-gallon tank, located immediately above residence No. 2, at an elevation of about 475 feet above sea level. Direct connections will be made from this tank to residences Nos. 1, 2, and 3. Another 60,000-gallon tank has been placed at the upper corner of the lower experimental fields, at an elevation of about 250 feet. Over 1 mile of piping has been laid to conduct water from this lower tank to the experimental plats. The materials for the construction of this water system, including two 60,000-gallon tanks and one 30,000-gallon tank, 12,000 feet of 1-inch pipe, 500 feet of 2-inch pipe, 400 feet of ¾-inch pipe, together with cement, dimension timbers for foundations, nails, roofing screws, pipe fittings, etc., cost $4,006.14. The plant was installed by day labor at a cost for labor and supervision of $993.75, leaving an unexpended balance of this appropriation of 11 cents.

Through delays in the delivery of materials on the part of some of the contractors this water system was not completed until after the end of the rainy season. Nevertheless, the tanks have been kept full practically all of the time, as hardly a day passes when there are not some showers at the elevation where the roof is placed. With an average rainfall amounting to about 120 inches per annum this water system will yield the station 1,250,000 gallons of water, and we now have a storage capacity of 210,000 gallons. This guarantees fire protection to station residences and office buildings, and insures a water supply for the experimental plats during the driest and hottest months of the summer, a period during which in previous years there has always been a shortage in the city water supply.

By using station labor under the immediate supervision of the director this plant was installed at a cost of less than 25 per cent of the cost of the materials used.

In July, 1906, two Wardian cases of cacao and six inarched mangoes were received from the Bureau of Plant Industry of the Department in Washington. A portion of these plants were set out on the station grounds in Honolulu and the remainder placed at Hilo, where previous plantings of cacao had been made.

The distribution of Bluefields bananas begun in May, 1906, was continued during July and August, over 1,000 suckers of this fine type of banana being distributed throughout the Territory.

In a cooperative agreement between the Director of the Office of Experiment Stations and the Chief of the Bureau of Plant Industry Dr. N. A. Cobb, who had been employed as pathologist by the Hawaiian Sugar Planters' Association in the study of the diseases of cane, was given a commission to prepare a report on the fungus diseases of crops other than cane in Hawaii, and this report will be published as a bulletin of this station.

The special agent, assisted by the station horticulturist and entomologist, made representations to the Territorial Board of Commissioners of Agriculture and Forestry in an endeavor to secure their cooperation in a survey to determine the present distribution of the mango weevil. This weevil, which is a very serious enemy of the mango fruit, as has been previously noted, had only recently been introduced into Hawaii, and it was felt that if precautions could be taken in time there was a good opportunity to entirely destroy the pest. The board of agriculture, however, considered that the weevil had already become so widely distributed throughout the group that it would be impossible to do anything, and the matter was therefore dropped. The officers of this station consider it extremely unfortunate that efforts should not have been made at the time of the first discovery of this mango weevil to prevent its further distribution.

The special agent made an extended trip through Maui and Hawaii in an investigation of the rubber industry. He also visited the location on Maui where the variety test of grapes was being conducted. As a result of reports made by him in regard to the suitability of certain lands in Puna, an extensive rubber plantation has been established, which has already (July 1, 1907) over 12,000 trees growing in the fields.

In November, 1906, this station cooperated with the manager of one of the local sisal plantations in an investigation of the sisal industry in Yucatan. Much valuable information was secured, which is available for publication in a second report on the sisal industry in Hawaii.

The special agent has prepared reports in regard to the work of the station for the governor of Hawaii, at his request, and also a report in regard to the cooperative work of the station for publication in the annual report of the Board of Agriculture and Forestry.

During the regular session of the legislature which convened in February, 1907, the director visited the island of Lanai at the request of the house committee, which had been appointed to investigate the Lanai land exchange, and made a report to the legislature on the agricultural possibilities of that island.

Considerable work has been done for other branches of both the Federal and the Territorial government, among these cement analyses for the U. S. Army Engineer Corps, and a number of analyses and examinations of imported goods for the collector of customs. This station has also cooperated with the Navy Department in sending collections of seeds and plants to the naval stations in Guam, Tutuila, and the Philippines.

A number of changes have occurred in the office and staff. The more important of these are the appointment of Mr. F. G. Krauss as agricultural expert in charge of rice investigations, at a salary of $2,000 per annum. Half of this amount during the fiscal year 1907 was contributed by the B. P. Bishop Estate (Limited). The horticulturist, Mr. J. E. Higgins, was promoted from $1,700 to $2,000. Miss A. R. Thompson was appointed assistant chemist, and the former chemist, Mr. E. C. Shorey, was transferred to the Bureau of Soils, U. S. Department of Agriculture.

Besides the $15,000 appropriated by Congress this station has received during the fiscal year 1907 from private and other sources $13,518.63. This includes a balance of $2,267.09 remaining unspent from the Territorial appropriation of 1905. A deficiency appropriation of $2,000 was made by the legislature in May, 1907, to assist the rice, tobacco, and rubber investigations. A Territorial deficiency appropriation of $1,873.86 was received to settle indebtedness which was

incurred in the erection of a fireproof library, laboratory, and office building, for the erection of which the legislature made an insufficient appropriation in 1905.

The Bernice Pauahi Bishop Estate (Limited), contributed $1,000 for rice investigations and $200 for rubber experiments. The Ii Estate (Limited), contributed $128, or its equivalent, in the free rental of 3.2 acres of rice land for the benefit of the rice investigations. The Honolulu Merchants' Association contributed $50 toward the cost of the fruit marketing experiments conducted by the horticultural department. Mr. James B. Castle contributed $358.60 toward the expense of establishing a citrus orchard on Tantalus, and $1,000 for tobacco experiments on Hawaii. The Hawaiian Bee Keepers' Association contributed $675 toward the cost of the entomologist's trip to Washington, D. C., in their behalf. Dr. Wm. S. Myers, of New York city, gave $187.50 for the continuation of the rubber experiments. Mr. George N. Wilcox gave $200 for rubber experiments and $500 for tobacco experiments. Hon. A. S. Wilcox contributed $500 for tobacco. Messrs. Geo. P. Thielen and Joseph P. Cooke each contributed $1,000 for tobacco. The American Sugar Company, the Parker Ranch, and the Stock Breeders' Association gave $175 toward the cost of investigations by the entomologist of insects affecting stock. The receipts from the sale of farm products amounted to $100.88. The total amount expended for this station during the fiscal year 1907 was $33,518.63, of which $20,000 was appropriated by Congress.[a]

During the year three press bulletins were issued—No. 17, The Mango Weevil; No. 18, All About the Hawaii Experiment Station; and No. 19, A Preliminary Report on Rice Investigations. Editions of 4,000 copies of each of these bulletins have been distributed.

CHEMICAL INVESTIGATIONS.

The only project completed during the year has been that of honey analysis. This work has been carried on by the station chemist, Miss Alice R. Thompson, in cooperation with the entomologist. Complete analyses were made of 49 samples of honey of known derivation and the results of this work are now available for publication.

Considerable routine work was accomplished, including a number of miscellaneous soil analyses, the analyses of waters to determine the relation of their salt content to the growth of rice and other irrigated crops, analyses of rubber, soils, and of additional samples of Hawaiian feeding stuffs.

---

[a] Besides these cash contributions the station is indebted to the Interisland Steam Navigation Company (Limited), of Honolulu; The Oahu Railway and Land Company (Limited), of Honolulu; The Kahului Railroad Company (Limited), of Kahului, Maui; and the Hilo Railway Company (Limited), of Hilo, Hawaii, for gratuitous transportation of the members of the station staff.

Early in the year connections were made with the mains of the newly organized gas company, so that we were able to discontinue the use of the cumbersome and costly gasoline gas machine, upon which the station had previously depended for its laboratory supply.

TOBACCO.

As has been noted above, the station received the benefit of $4,000 in private contributions for continuing the tobacco investigations, concerning which a number of reports have been issued. In January, 1906, the station was given the use of lot 19, Paauilo Homestead, a body of land about 1 mile distant from the plat which had previously been leased from the Louisson Brothers, in Hamakua, Hawaii. At the request of the special agent, the acting governor of Hawaii, Hon. A. L. C. Atkinson, secretary of the Territory, confirmed a reservation made by Hon. James W. Pratt, commissioner of public lands, reserving lot 19 for the use of the station for a period of three years. Field work was not begun until February 15. Three thousand dollars of private funds being at that time available, the work of preparing land for planting was immediately begun. A part of the land was cleared of the abandoned coffee, with which the land was covered, along with weeds and grass. About 2 acres was then plowed and 3 acres intended for immediate planting was partially hoed and then cultivated. As soon as the ground was in shape transplanting was begun. Work was commenced so late in the year that we were able to plant only about 3½ acres, instead of 5 or more, as originally planned. As soon as the field work was under way lumber was purchased for the erection of a curing barn and fermenting shed, seed houses, and labor quarters. A curing barn capable of handling 5 acres of tobacco was rushed to completion, but even then some of the tobacco was overripe before the structure was finished. About $2,500 of the amount privately contributed was expended for buildings and other permanent improvements. The work was begun late in the year, so that everything was hurried during the entire season.

The results were better than in any previous season. The entire crop was cured and fermented in the new tobacco barn, and, although probably 600 pounds of the crop was lost through ripening before we were ready to care for it, a crop of 3,000 pounds of cured tobacco was secured from 3½ acres of land. A quantity equal to 6 or 7 bales has been distributed in small amounts to tobacco dealers in the United States and Europe. Two New York firms received 1 bale each, and the station now has on hand 23 bales of finished tobacco. The best tobacco grown this year was the Sumatra, although the Cuban grades were of very excellent quality. The reports in regard to the quality of our tobacco are uniformly favorable, buyers being very enthusi-

astic in regard to colors, texture, and burn of leaf. The tobacco is very mild and of excellent flavor.

The legislature at its session early in 1907 having omitted its appropriation for assistance to this station, the demonstration with this crop was discontinued. It is believed that this demonstration, which has been continued over a period of three years, has definitely established the fact that cigar-leaf tobaccos of the very best wrapper and filler types can be produced on a commercial scale in certain favorably located districts in Hawaii.

ENTOMOLOGICAL INVESTIGATIONS.

In July and August, 1906, the entomologist finished his work with the distribution of the top-minnows. He personally distributed a number of these mosquito larva-eating fish on the windward side of Oahu, in the vicinity of Hilo, on the island of Hawaii, and on several points on the island of Kauai. This distribution having been completed, this line of investigation was discontinued.

In September, 1906, a request was made for the services of the entomologist in the control of a serious outbreak of pineapple insects on the island of Kauai. The cause of serious losses among fields of newly set pines was found to be the pineapple scale and the pineapple mealy bug. Experiments were made both in dipping and in fumigating the suckers which were being transplanted. It was found that the hydrocyanic-acid gas method was entirely efficacious, cheap, and easy of application.

The principal entomological work of the year has been an investigation of the problems affecting the honey industry in Hawaii. The entomologist has visited all the principal apiaries and has made a very exhaustive study of the conditions of the industry. Fifty-four samples of honey of known origin were collected; 49 of these were analyzed by the station chemist.

Hawaiian honeys are largely of a type entirely different from those of the mainland. The present annual production amounts to upward of 600 tons. One-fourth of this, or about 150 tons, is honeydew honey, the source of which is not floral nectar, but the secretions of insects affecting the sugar cane and other sugar-producing plants. About 250 tons are a mixture of honeydew honey and floral honey, compounded by the bees during the time when there is a shortage of floral nectar. About two-thirds of a crop is therefore of a type but little known on the mainland. This pure honeydew honey and the mixed honeys are sold to the baking trade, and do not enter into competition with any of the natural product offered for sale in the retail markets.

Through the efforts of the entomologist the prices obtained by producers of this honeydew product have been much increased. Be-

fore their baking qualities were ascertained, the Hawaiian honeydew honeys entered into more direct competition with Australian and other cheap grades, which are most largely used in the manufacture of shoeblacking and in other special lines of industry. In former years, when only this market was known to be open, prices ranged from 2 to 3 cents per pound. Now, through the efforts of our entomologist, large consignments have been sold to the wholesale baking trade, prices ranging from 4 to 6 cents per pound being realized.

Bakers and confectioners consider honey of this type, on account of its noncrystallization, as much more valuable in their industry than the grades obtained from purely floral sources.

On April 5, 1907, the entomologist left for Washington for the purpose of taking up with the Chief of the Bureau of Chemistry the question of the conformity of Hawaiian honeys to honey standards. Subsequent to the passage of the Food and Drugs Act, the question had arisen whether or not Hawaiian honeys of the pure honeydew and mixed honeydew types were or were not adulterated. Mainland buyers claimed that these honeys were not pure. The analyses of Hawaiian honeys, made by the chemist of this station, had plainly indicated that while these honeys are pure in the sense that they are not artificially adulterated, there is wide divergence in their analysis from previous honey standards.

While somewhat abnormal in their constituents, these honeys are recognized as natural products, and as such can be marketed if properly labeled. Those polarizing to the left will be recognized as pure honey, while those polarizing to the right should be marked in a distinctive manner, and the name "honeydew honey" has been suggested for them.

In connection with this honey work a beginning has been made in the investigation of the feasibility of feeding back the inferior grades of pure and mixed honeydew types for the production of wax. Wax of good quality sells for from 35 to 40 cents per pound, while honeydew honeys sell from $2\frac{1}{2}$ to $4\frac{1}{2}$ cents per pound. If it proves practicable to feed back this grade of product, or, more properly, if 1 pound of wax can be produced by feeding back from 4 to 8 pounds of honey, there is bound to be a wider margin of profit in the production of wax than through the marketing of this cheap grade of honey.

Studies were also made of the races of bees with a view to improvement of the local breeds.

Another line of investigation which has been begun is a study of the insects affecting live stock, among these being flesh flies, horn flies, mites, ticks, bots, fleas, and other pests. On his return from Washington the entomologist visited some of the ranches in Texas and southern California, making preliminary studies of the conditions affecting pests of stock in these sections of the country.

Investigations were continued on household pests and pests infesting stored products, and a demonstration was made of methods for the control of the cigarette beetle in tobacco and cigars. The cigarette beetle occurred in a new rôle as a household pest, being discovered in enormous numbers in a residence in Manoa Valley infesting the paste underneath the wall paper.

Other outbreaks of minor importance were investigated, such as an epidemic of fleas in several sections of the city. Considérable losses in furniture and basket ware, caused by termites, various wood-boring insects, and the bamboo beetle, were prevented.

As the rubber industry is attaining considerable proportions, studies have been commenced of the injurious insects affecting rubber trees. The entomologist visited the rubber plantations on Maui, and has made studies of the life histories of some of the bark and wood-boring insects with a view to their control.

HORTICULTURAL INVESTIGATIONS.

The principal work of the year was a fruit shipping experiment. The horticulturist left Honolulu August 1, 1906, taking with him about 4 tons of pineapples, avocados, papaias, and bananas. This shipment was landed in San Francisco August 7 and was transshipped at once to Portland, Oreg., where the entire shipment was unpacked and examined. A portion of it was disposed of in Portland and the horticulturist took the remainder to Astoria, Tacoma, Seattle, and Vancouver. Returning to San Francisco he visited Fresno to investigate the sweet-potato industry. He also investigated the general fruit markets in San Jose, Stockton, Sacramento, and Oakland, and, before returning, visited Luther Burbank's gardens in Santa Rosa. The object of this comprehensive experiment was to determine the best methods of packing, handling, and marketing tropical fruits. An investigation was also made of the extent of the market for these fruits on the Pacific coast. Selected packages were shipped to commercial bodies and to the governor of each of the mountain States as far east as Colorado. One package of pineapples was shipped to the special agent in charge of the Alaska Experiment Station at Sitka. This experiment demonstrated the possibility of the shipment of avocados and pineapples in cold storage to any point which can be reached by direct shipment from Honolulu, Hilo, and other island ports. Interesting facts were determined in regard to methods of packing and the use of different styles of crates. The most striking feature of the whole experiment was the demonstration of the value of fumigation with formaldehyde gas to prevent the losses caused by the pineapple rot, *Thielaviopsis ethaceticus*.

This fungus is the cause of the disease of sugar cane known as the pineapple disease; so-called, not because it was originally a disease of pineapple, but on account of the odor which is produced in cane affected by this disease. In cane it is a disease of the ripe stalk, the fungus attacking the plant at the stage when it contains the most sugar. When this fungus attacks the pineapple it is chiefly in evidence during the ripening of the fruit and does not apparently affect any other part of the plant. It has been demonstrated that infection of the pineapple fruit occurs at the base, either through wounds caused by mealy bugs and other sucking insects, or where the fruit has become bruised or injured through the tearing off of the bracts which subtend the fruit. The fungus also gains entrance to the fruit through the fresh surface of the cut stem. Positive results were obtained when these bracts were cut instead of being pulled, and equally positive results were obtained by cutting the stalk 2 or 3 inches below the fruit. Preliminary experiments were made in dipping the fruit in a 4 per cent solution of formalin, but it was found that this method caused changes which would interfere with the attractiveness of the fruit. It was found that fumigation caused none of these changes, but did exercise a definite control to prevent infection. The fumigated fruits which were lost by rotting in transit were those which were apparently seriously infected previous to shipment and previous to fumigation. It was demonstrated that a favorable method of fumigation is that proposed by the Maine State board of health, through the use of permanganate of potash and commercial formalin. A full and detailed account of these experiments was published in a bulletin of this station.[a]

Other points which were determined in regard to pineapples are the value of glazed paper as a wrapping material for the fruit. By the substitution of paper for hay or straw, which substances are commonly used in the packing of Hawaiian fruit intended for shipment, the package can be decreased at least one-third in size and the weight also very considerably diminished. Pineapples that were wrapped in paper reached the market in very much better condition than those packed with hay in crates.

The permanent orchards on the station were largely increased during the year 1907. The avocado and mango orchard was extended so that about 1½ acres are now planted with budded, grafted, and inarched stock of many of the best varieties.

Through the cooperation of Mr. James B. Castle, about 2 acres of land were cleared on the upper portion of the place at an elevation of about 1,000 feet. This has been planted with a collection of some of

[a] Hawaii Sta. Bul. 14.

the best Californian varieties of citrus fruits, figs, loquats, and grapes. About one-third of an acre has been planted with papaias for breeding and crossing work. A large number of seedling citrus trees have been set out with a view to making in this location a bud collection of the best island types. Besides contributing funds for clearing the land and planting it, Mr. Castle has volunteered to care for the orchard during the coming year.

A large collection of rubber plants and miscellaneous economic plants has been set out on the clearings above the 1,000-foot level. These were all grown by us in our greenhouses from seeds purchased from dealers in tropical seeds and plants.

On the lower part of the place about 4 acres of new land has been planted, as follows: One acre of mulberries, obtained through the Bureau of Entomology, U. S. Department of Agriculture. This planting represents the best varieties for the production of silk, so that the station will have its own supply for further investigations in this line of work. One acre has been planted with citrus trees including grapefruits, oranges, lemons, and limes. One acre has been set with 5 species of rubber—*Castilla elastica*, *C. lactiflua*, *Manihot glaziovii*, *Cryptostegia madagascarensis*, *and C. grandiflora*. The remaining acre has been planted with a miscellaneous collection of tropical fruits and economic plants, including stock grown in our own greenhouses and plants supplied by the Seed and Plant Introduction of the U. S. Department of Agriculture.

About 1½ acres of roselle was cultivated on the lower part of the station as a demonstration of the practicability of growing this fine fruit. A quantity of the fruit was sold, and a good many lots were distributed for the purpose of demonstrating its value in the making of jams and jellies. Seed was saved from selected plants and has been widely distributed throughout the Territory.

The horticulturist visited the Parker ranch, on the island of Hawaii, supervised the setting out of a large deciduous orchard, consisting of apples, pears, plums, peaches, apricots, cherries, walnuts, almonds, and figs. Two orchards of deciduous fruits have been established on the Parker Ranch, one at an elevation of about 3,000 feet, on the northeastern end of the ranch, and one at 5,000 feet in the Waiki district. This cooperative experiment will undoubtedly prove of great value in subsequent years.

The horticulturist had the general supervision of a fruit exhibit in connection with the agricultural show held in Honolulu, December, 1906. In cooperation with the Hawaiian Poultry Association the horticulturist prepared an exhibit under the joint auspices of the Farmers' Institute of Hawaii and the Hawaii Agricultural Experiment Station.

RUBBER.

In the summer of 1906 attention was called to the existence of two groves of rubber trees on the island of Kauai, each containing about 100 individual trees. One of these groves, at Koloa, was planted in 1893, and seed from these trees was planted at Lihue in 1899, so that the two groves are, respectively, 13 and 7 years old. These trees are of the Ceara variety, which is being extensively planted in these islands.

It was at once suggested by some of the planters interested in rubber cultivation that this station make a tapping experiment to determine the amount and quality of rubber obtainable. As this station had no funds, work was not begun until January 1, 1907, when the B. P. Bishop Estate (Limited), and Mr. George N. Wilcox each contributed $200 to assist the work.

The first work done was on a few isolated trees from 4 to 10 years old on the experiment station grounds in Honolulu. Three months were devoted to laboratory investigations in regard to the behavior of the latex under different coagulents. Some preliminary work was done to determine the form of tapping tools and method of tapping.

In April, a satisfactory method having been worked out, the special agent, accompanied by Mr. Q. Q. Bradford, farm foreman, went to Lihue. The management of the Lihue plantation lent the station hearty cooperation, erecting a small shed in the rubber grove and providing entertainment and horses for the use of our foreman. The Lihue grove of 7-year-old trees occupies an old taro patch in the bottom of a gulch. Surrounding it is a planted forest several hundred acres in extent. A living stream of water runs through the middle of the grove and the land is quite swampy. The trees vary greatly in size, from 6 inches to 30 inches in circumference of trunk, at 3 feet from the ground. No care appears to have been given the trees during the entire period of their growth. Some of the trees show a clear, straight trunk, 30 feet in height; others fork near the base. It was found that only about 70 trees out of the full number, 110, were suitable for tapping, owing to their size or shape.

A set of rubber tapping knives such as are used in Ceylon for work on Hevea had been purchased, but it was soon found that these were entirely unsuited for thin-barked trees like the Ceara, and considerable work was devoted to making a form of knife which would be satisfactory. After many experiments the system of tapping decided upon was the half herringbone, with one vertical cut and laterals a foot apart extending half around the tree. Where the full herringbone system was employed it was found that only the uppermost and lowest laterals yielded a full flow of latex. Two experiments were outlined, one to tap every day, the other alternate days.

The Ceara latex coagulates almost at once when the channels are made. We therefore adopted a method of trickling water over the cut surfaces, and soon found an addition of ammonia retarded coagulation and continued the flow until the feeding area was practically exhausted. The mixed water and latex is collected at the foot of the tree. The tapping was begun at 5 o'clock a. m. Two trees averaging 28 inches in circumference were tapped for nine consecutive days, with the full herringbone system from the ground to 5 feet, there being five laterals 1 foot apart. These two trees yielded 8 ounces of dry rubber in nine days. Two other trees were tapped on alternate days for a period of two weeks and yielded 4 ounces of dry rubber in that time.

Work was begun at Koloa in May. The trees, 44 inches in circumference and 13 years old at the time tapping was begun, were almost bare of leaves, the resting period being about ended. Two of these 13-year-old trees were tapped every day for nine days and yielded $12\frac{1}{4}$ ounces of dry rubber. It was not considered advisable to tap alternate days on account of the leafless condition of the grove.

In June a number of 4-year-old trees at Koloa, averaging 19 inches in circumference, were tapped every day for 9 days, yielding only $\frac{1}{2}$ ounce of dry rubber. These trees were entirely bare.

This tapping work has been very suggestive, and there are many points that have arisen which we shall endeavor to work out during the coming year. The Ceara trees seem to be very susceptible to the atmospheric and other conditions, at least as far as the flow of latex is concerned. The flow is apparently greatest in the early morning at about sunrise. The amount of sunshine received by the tree apparently has some influence on the amount and flow of latex. These experiments are only in the preliminary stage, and it is too soon to draw conclusions, but if any results can be predicated the indication very strongly suggests the value of daily tappings rather than tapping the tree at longer intervals. Trees tapped late in the forenoon, at midday, or in the afternoon, yield almost no latex. At about sundown there is apparently an increase of tension and the latex flows more freely.

Four-year-old trees at Koloa yielded at the rate of 10 ounces of dry rubber per tree per annum, supposing it possible to tap every day. Seven-year-old trees at Lihue yielded at the rate of 10 pounds per tree, while 13-year-old trees at Koloa yielded at the rate of 15 pounds of dry rubber per tree. Neither the Koloa nor Lihue trees were in good condition at the time of tapping. Those at Lihue are in a swampy location, where the ground is always saturated with water. Those at Koloa are in a much drier location, but have been choked with guava and lantana and overrun with vines. All the tappings were made while the trees were just entering their period of rest or

during the time when bare of leaves. Nevertheless, the results are encouraging. The indications are that the Ceara rubber tree will grow in almost any location in these islands, from sea level to 2,000 feet, and wherever the conditions are sufficiently favorable to permit the attainment of a trunk diameter of 7 or 8 inches these trees will yield an enormous quantity of rubber of most excellent quality.

The quality of the rubber has been good. The variations in quality apparently depend more upon the coagulating medium than upon the character of the latex itself, although in this respect there is wide variation. A great many experiments have been made with various methods of coagulating the latex, but it is too soon to announce results. The best qualities thus far produced have been made by neutralizing the ammonia in the latex and coagulating by adding a hot concentrated solution of ammonium sulphate to which a small amount of formalin has been added. Other coagulents that have been experimented with are acetic acid, sulphuric acid, tri-chloric acid, formic acid, sea water, ammonium sulphate, various copper and other mineral salts, sodium sulphate, etc. A very excellent quality of rubber may be separated out by simply churning the mixture of water and latex. Sulphuric acid gives goods results, provided but little more than enough to neutralize the ammonia in the mixture is used. An excess of sulphuric acid apparently causes deterioration in the quality of the rubber.

RICE.

An investigation of the problems of the rice industry was begun July 1, 1906, funds for the purpose of a cooperative experiment having been provided by the Bernice Pauahi Bishop Estate (Limited), and the Ii Estate (Limited). The trustees of the Bishop estate gave $1,000 for this work, and the Ii estate contributed the lease of 3.2 acres of rice land, located at the junction of King street and Kalakaua avenue, in the city of Honolulu. Mr. F. G. Krauss, who had been agricultural instructor at the Kamehameha Boys' School for the preceding five years, was appointed an agricultural expert in this office to have charge of the work. Operations were commenced about August 1, 1906, and consisted of variety tests of 130 different rices obtained in the islands through the Bureau of Plant Industry, U. S. Department of Agriculture, and through the bureau of agriculture, Manila, P. I. In addition careful selections had previously been made from individual plants, representing some of the best strains of rices now being grown in Hawaii. Two crops of rice have been grown during the period from August 1, 1906, to August 31, 1907.

The results of the variety test have been that one variety, seed of which was originally obtained by Dr. S. A. Knapp in Egypt, has proved to be better than any rice ever grown in these islands. This

Egyptian strain has a very large, flinty grain, heavy panicle, heavy straw, good leafage, and is of the type demanded by the largest consuming trade in these islands. Its milling qualities are very much superior to those of any other variety which has been produced in the islands, the hulls approximating only 20 per cent of the total weight of paddy, as compared with from 26 to 30 per cent for the best Japanese types, and 28 to 36 per cent for the ordinary Hawaiian variety. In addition to this Egyptian type three other strains have shown marked superiority to the ordinary Hawaiian-grown rices. These are, in order of merit, a Philippine variety, a strain of the Gold Seed from Georgia, and a Japanese type, seed of which was secured direct from Japan.

This Japanese variety produces a crop in three-fourths the time required for the maturity of the Hawaiian variety, provided it is transplanted from the seed bed at the proper time. It is of the Kiushu type, yields as heavily as the Hawaiian variety, mills from 10 to 12 per cent better, produces only about two-thirds the amount of straw, and is therefore less exhaustive on the rice lands. It is the type of rice now most largely consumed in Hawaii by the Japanese laborers on the plantations. A further advantage of the adoption of this variety will be that two crops can be grown each year, with a long rest between crops to permit the drainage of the fields and their better tillage and preparation. The station now has 50 pounds of this seed on hand, and will probably have 1,000 pounds at the end of the next crop. The field was thoroughly rogued and the strain is being propagated from the best individual plants of the whole field, thus laying the foundation for the production of pedigree rice.

The so-called Hawaiian rice is derived from original Gold Seed, South Carolina stock, the first rice cultivated in Hawaii having been thus obtained. The Georgia variety, mentioned above, is hardly to be distinguished from Hawaiian rice. A number of selections have been made of individual plants showing the best individual characteristics in yield of grain, form of panicle, stalk, and leafage, and vigor of growth. An increase of 25 per cent of yield of paddy has already been produced from only the second selections from individual plants. The advantage of this use of pedigree stock of seed derived from a single parent is greater uniformity in the size of grain, the yield, and the time of ripening. The substitution of such pedigree stock will tend to decrease the very large milling losses which have been characteristic of the Hawaiian rice industry. The ordinary Hawaiian rice, while largely of the Gold Seed type, is really a mixture of a great many different types, so that to get the best results in harvesting some of the rice will be so ripe that the grain shatters, while a portion of the plants in the field have perhaps barely attained a sufficient degree of ripeness to warrant their being cut. The losses in milling are

due to the varying sizes and types of grain and their varying stages of maturity. The miller sets his burrs to accommodate the average size of grain in the run, so that grains which are too large are broken and those which are smaller than the average are insufficiently milled, causing bad color in the product.

The uniformity of grain will undoubtedly prove of greater importance than any other single factor in the production of this crop. This uniformity can be produced only by the production of pedigree stock; that is, stock derived originally from a single parent plant.

Three varieties of dry-land rice have been selected from the original variety collection. An interesting point about these dry-land rices is that they produce a better crop without irrigation than with it. The value of dry-land rice is going to be not so much the production of grain, because dry-land rices tend toward the starchy type of grain rather than the flinty, but the production of forage. The culm and leafage of the dry-land types of rices are soft and pliable, lacking the silica that causes the harshness of irrigated sorts. These strains produce a quality of hay which is greedily eaten by horses and cattle. The present outlook is that dry-land rices will fill a very important need in Hawaii in the production of hay and forage.

Fertilizer experiments have been conducted for two crops in pot, plat, and field experiments. While it is perhaps too early to draw conclusions, the indications are that an increase of from 15 to 20 per cent of grain per acre can be induced by use of commercial fertilizers of suitable composition.

Early in the year orders were placed for a number of types of agricultural machinery not hitherto used in the rice industry in Hawaii. These included disk tillage implements and the twine binder. Disk tillage is promising, provided machinery can be secured which will give a penetration of from 6 to 8 inches. The type of cut-away, or disk plows and disk harrows, which the station has secured, would only penetrate about 4 inches, although the manufacturers claimed a much greater penetration. It was found that 4.5 acres of rice land could be plowed per day with a 5-foot cut-away bog plow and four horses, as against from 1 to 1½ acres with two water buffalo, or from three to four horses on a 10-inch mold-board plow turning the soil to a depth of about 6 inches. This is the only advantage which this form of implement has over the improved types. If manufacturers of disk implements will evolve a type of bog plow that will turn the ground from 6 to 8 inches in depth, there is no doubt that they would be immediately adopted by the Chinese rice growers.

A number of trials were made in the harvesting of rice with a 5-foot twine binder harvester, and it is believed that the Chinese rice growers would adopt this type of machinery if they could secure a lighter machine.

With an extra week's drainage previous to harvesting, fully one-half of the total area of rice lands in Hawaii can be harvested by means of machinery. The results of the preliminary harvesting tests indicated that even with our comparatively heavy machine one good team of two heavy draft horses, or from three to four medium horses and three men—that is, a driver and two men to follow the machine and shock the grain—will do the work of from 25 to 40 men cutting with a sickle. The increasing shortage of labor in the rice fields and the corresponding increase in prices of day labor will make the substitution of machinery for hand methods imperative. The expert in charge of rice investigations is in correspondence with a number of manufacturers in the United States to see whether a light machine can not be produced which will do the work required of it.

REPORT OF THE ENTOMOLOGIST.

By D. L. Van Dine.

INTRODUCTION.

Correspondence, the collection of economic insects, the entomological library and records demand a great part of the time of the entomologist. The collection contains only the principal injurious insects of the islands, together with allied species and some of their parasitic and predaceous enemies. The specimens are arranged in exhibition cases, are authoritatively determined, and form no small aid in acquainting those interested with any particular species under consideration. To combat intelligently an insect pest the individual must know the appearance, form, life history, and habits of the species and the nature of the injury. To this end the collection is principally devoted.

As to the records, their units seem insignificant alone, but together they form a detail of information that can be brought together with effect in dealing with an insect of economic importance. The value of these records will increase as accessions are made from year to year.

Important additions have been added to the library during the year. Those relating to Hawaiian entomology are included in this report.

The writer visited Wahiawa, Oahu, and Koloa and Lihue, Kauai, to study further the insects affecting the pineapple. Trips were made to Pearl City and Waianae, Oahu, in the interests of bee keeping. Personal investigations relating to the scale insects attacking the mango and fig and spraying experiments to control the same were made at Moanalua, Oahu. Detailed studies of the insects affecting live stock in Hawaii were begun on Molokai. A trip involving three months' time was made to Washington, D. C., southern Texas, and southern California, in the interests of Hawaiian honey, plants suitable for introduction into Hawaii for bee pasturage, and insects affecting live stock.

The writer takes advantage of this opportunity to express his gratitude for continued courtesies extended during the year by mainland and foreign workers. Particular mention should be made of the

helpful aid in information, suggestions, and determination of material received from Dr. L. O. Howard and his associates of the Bureau of Entomology of the United States Department of Agriculture.

INSECT INJURY IN HAWAII.

In Hawaii the relative loss from insect injury is considerably higher than on the mainland of the United States. In the latter it is estimated to be not less than one-tenth of all farm crops. Local opinion has been molded to attribute the unusual injury from insect pests in Hawaii to the fact that Hawaiian conditions are radically different from those of other countries, and especially those in other portions of the United States. This explanation is a very plausible one when supported by the further facts that the country is insular, one of the most isolated portions of the earth's surface, semitropical in climate, and the injurious species of insects are introduced from abroad, and in the majority of instances are unaccompanied by their special parasitic or predaceous enemies. The conclusion is that remedies applicable elsewhere are not practical here. However, the "peculiar nature" of Hawaiian insular conditions and climate comes far from explaining the reason for the greater ravages of Hawaii's insect pests. The term "peculiar" has come to possess an importance it does not deserve.

Hawaii has conditions peculiar to no other country, but in that respect is similar to every other country—each differing according to its own altitude, latitude, and climate. Details of the differences in pests, crops, methods of agriculture, climate, and differing habits of the host or pest under the varying conditions of location will indicate modifications in the methods of insect warfare to be employed. It is to be admitted that conditions peculiar to any country or locality necessitate a variation in the methods of insect control, but this variation is only in the methods and not in the fundamental principles underlying the science.

The following conditions contribute to the relatively high ratio of insect injury in Hawaii as compared with the percentage of loss on the mainland:

(1) Cultural methods in relation to insect injury and the use of insecticides have been little understood on the plantation and on the farm. Until there is a more general effort to control the insect pests of Hawaii by cultural and direct measures, it will be unfair to compare conditions in Hawaii as regards insect injury with those of another country where such measures are universally employed.

(2) Sugar-cane is the principal agricultural crop of Hawaii. An enemy of this plant has necessarily a great advantage because of the immense area devoted to its cultivation. Aside from the advantage of abundance of food, the growth of cane, unlike wheat or corn in a

temperate climate, is continuous. In any locality it is possible to find sugar-cane in various stages of development at all seasons of the year. Not only an abundance of food, but a continuous supply is assured. Further, until recent years varieties of cane and its culture were not considered in their relation to insect injury. Thus when an introduced pest, the sugar-cane leaf-hopper (*Perkinsiella saccharicida*), made its advent into the cane fields several years ago, its injury amounted to millions of dollars.

(3) There is no check to insect development in Hawaii by radical changes of temperature, the equable climate favoring the development of brood after brood throughout the year.

(4) The efforts of diversified farming have been undertaken, in the majority of instances, on land recently cleared and in the midst of areas not under domestication. These smaller areas under cultivation have naturally attracted a horde of injurious insects, present in the locality but inconspicuous because of the check that natural conditions enforce. Further, the individuals undertaking the efforts of farming have in many instances not been farmers and have been unprepared for insect injury and helpless when the destruction of the crop has been threatened.

(5) Horticulture is an undeveloped industry. The effort to produce fruit is confined mainly to trees and vines growing under most adverse conditions in crowded dooryards, uncultivated and uncared for. The percentage of insect injury is abnormally high under these conditions.

(6) Crop rotation, a powerful factor in the control of injurious insects in many countries, is not practiced in Hawaii. Agriculture in Hawaii is not a combination of general farming industries, but is necessarily devoted to crops that must seek the world's market and are thus highly specialized.

(7) Injurious species of insects have been introduced without their special parasitic and predaceous enemies. This has given a great impetus to the development of some species because of the absence of one of nature's important checks. A great deal has been done on the part of the local government to remedy this condition by the introduction from abroad of many important special enemies of some of the more prominent insect pests.

(8) While legislative action is rigidly enforced to prevent the further introduction of injurious insects, no regulations have been outlined or enforced for the destruction of injurious species already established. There is little incentive for an individual to destroy the pests of his own trees and plants when indifferent owners all about him are allowed to breed unlimited numbers of the same species.

THE SWEET-POTATO WEEVIL.

(*Cylas formicarius.*)

The sweet-potato weevil (see fig. 1) appeared in injurious numbers in sweet potatoes at the Lahainaluna School on the island of Maui in January, 1907. Specimens of infested potatoes (see fig. 2)

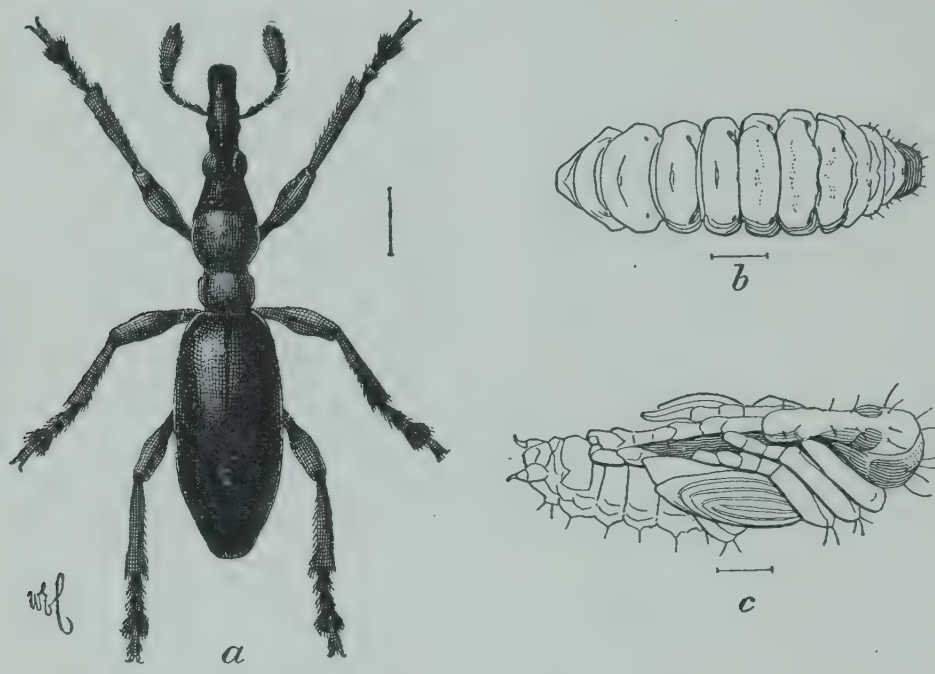


FIG. 1.—The sweet-potato weevil (*Cylas formicarius*): *a*, adult; *b*, larva; *c*, pupa. All greatly enlarged. Natural size shown by lines. (Drawn for the author by Mr. W. E. Chambers.)

were received from Mr. Charles Flack, at that time agriculturist of the school. The crop was nearing maturity and was practically destroyed. The insect is of long standing in Hawaii, being recorded

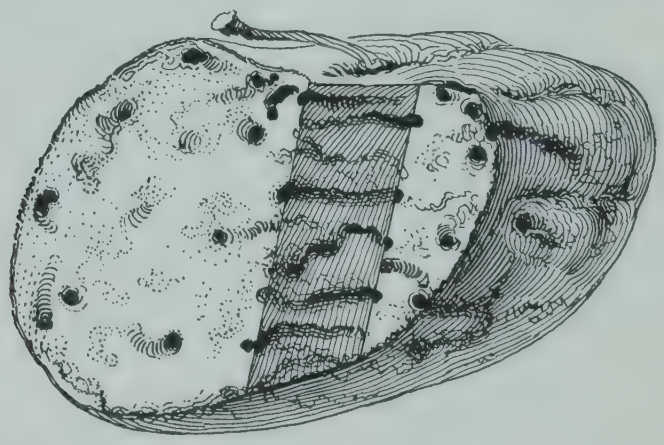


FIG. 2.—Injury to sweet potato by larvæ of the weevil (*Cylas formicarius*). (Drawn for the author by Mr. W. E. Chambers.)

by Blackman and Sharp from the islands of Maui and Oahu in 1885 under the name of *Cylas turcipennis*.[a]

[a] Memoirs on the Coleoptera of the Hawaiian Islands. Sci. Trans. Roy. Dublin Soc., 2. ser., 3 (1885), p. 253.

This is the first local injury that has come to the attention of the writer. Should the attack of this weevil on sweet potatoes become general it would mean a great hardship to the Hawaiian people in some of the outlying districts, since this crop supplies the staple article of food in many localities.

A common plant in all sandy soil along the seacoast of the islands is a vine the name of which is Pohuehue (*Ipomœa pes-caprœ*). This vine is likewise a food plant of the sweet-potato weevil and the destruction of this plant in the neighborhood of sweet-potato fields would be a good precautionary measure. The writer advised Mr. Flack to dig the potatoes and destroy those unfit for use, and cease to plant that crop for one or two seasons, substituting some other crop to replace the sweet potato on the school table. On the advice of Mr. J. E. Higgins, horticulturist of the station, the Polapola banana (*Musa fehi*), a cooking banana of good quality, was recommended to replace the affected crop.

Le Conte and Horn record the sweet-potato weevil in 1876 from Cochin China, India, Madagascar, Cuba, and Louisiana.[a]

Comstock in 1880 reports the destruction of sweet potatoes by this insect in Florida and gives the following description of the weevil and its life cycle:

> The beetle is somewhat ant-like in form. The color of the elytra [wing covers] and of the head and beak is bluish black; that of the prothorax is reddish brown. The yellowish-white oval eggs are laid in small cavities eaten by the parent beetles near the stem end of the tuberous roots. The milk-white larvæ bore little tunnels through the root in all directions, so that the vine dies; and frequently the entire potato is tunneled; these burrows become filled behind the larvæ with excrement. When about to assume the pupa state, the insect forms an oval cavity at the end of its burrow, where it undergoes its transformation.
>
> At the time of my visit to Manatee County, in February, only the perfect insects could be found. On the 17th of May potatoes containing eggs and beetles with a few pupæ were received from Mr. Curry. In our breeding jars these underwent their entire transformation from egg to imago in about thirty-one days, of which eight days were passed in the pupa state. From this it appears that during the present season there have already been at least three generations, and it is impossible to say how many more may appear.[b]

In regard to remedies for the sweet-potato weevil, Riley and Howard say:

> Up to the present time no remedy has been found except to burn all potatoes which are found to be infested. If this should be carefully and thoroughly done throughout a neighborhood, the pest could be greatly reduced. * * * Where it has been abundant in Florida it has been practically stamped out by following the measures just recommended.[c]

---

[a] Rhynchophora of America, North of Mexico. Proc. Amer. Phil. Soc., 15 (1876), p. 327.

[b] Report of the Entomologist, Rpt. Comr. Agr. 1879, Washington, 1880, p. 249.

[c] U. S. Dept. Agr., Div. Ent., Insect Life, vol. 5, 1893, p. 261.

In referring to the sweet-potato weevil in Jamaica, the same writers say:

> It seems that only tubers of a certain size are attacked, and early digging sometimes avoids the attack. Sandy soil and deep planting are said to be preventives to some extent.[a]

Undoubtedly the destruction of an infested crop will better insure freedom from attack in the succeeding crop. Deep planting, however, can not be practiced in Hawaii, since cuttings and not tubers are used for seed. After the cuttings have rooted, deep hilling could be employed and the same point gained. If the sweet-potato weevil does become abundant in any locality, probably the best solution of the difficulty for the Hawaiians will be the substitution of some other crop, as the banana, dry-land taro, or upland rice.

THE MELON FLY.

(*Dacus cucurbitæ.*)

Until the winter months of 1898 all cucurbits (watermelons, muskmelons, squashes, pumpkins, cucumbers, etc.) could be grown in Hawaii in abundance and with comparative ease. From that time the increase of an introduced enemy, an insect pest that has come to be known locally as the melon fly, has all but stopped the growing of these products. Mr. B. O. Clark states that he was growing melons at Pearl City, Oahu, at that time and first noticed the fly in the summer of 1897, and that the pest increased to such an extent by the winter months of 1898 and 1899 that attempts to grow melons were given up after those years.

From 1899 to 1903 watermelons and muskmelons, previously very profitable crops, were not grown to any extent. For several seasons past, however, the production of these crops has been on the increase. The reason for this is undoubtedly the persistence of the Japanese growers in protecting their melons from the flies at or immediately after the setting of the fruit. From observations made during the year the writer is of the opinion that watermelons at least can be grown at a good profit.

The first record of the food plants and injury of the melon fly were made in 1898 by Mr. B. O. Clark, then commissioner of agriculture of the local government. The remedies that Mr. Clark suggested at that time, namely, the covering of the infested fruit and vines and the destruction of the infested melons, are today the most effective measures employed against the pest. The reference is as follows:[b]

> The following letter from Mr. Swain makes inquiry about one of the most serious pests on these islands. The reply may interest others:

---

[a] U. S. Dept. Agr., Div. Ent., Insect Life, vol. 6, 1893, p. 44.

[b] Official Bulletin of the Bureau of Agriculture. The Hawaiian, Vol. I, No. 27, p. 6. Honolulu, 1898.

"LAUPAHOEHOE, *August 8, 1898.*

"Professor KOEBELE, *Honolulu.*

"DEAR SIR: We have a new pest that has lately come here in the shape of a fly like a yellowjacket, only not so large. It punctures pumpkins, squashes, beans, tomatoes, watermelons, and all other plants of this nature. It lays eggs inside, which form maggots like the samples I send you. You can judge of their work where the things are growing. Can you suggest any remedy? I send you some samples of their work by the S. S. *Kinau.*

"Yours, truly,

"L. C. SWAIN."

"HONOLULU, *August 11, 1898.*

"L. C. SWAIN, Esq., *Laupahoehoe, Hawaii.*

"DEAR SIR: Yours of the 8th instant at hand and contents noted. Professor Koebele is now in the States, but as I have personal experience with the fly you mention and consulted with Professor Koebele in regard to it, I can state he told me of no remedy except covering the vines, and of course this is not at all practicable except for a few vines in a garden. I tried a spray of whale-oil soap, thinking the odor might keep the fly away, but it did not. I shall try a Paris green solution, 1 pound to 200 gallons of water, keeping it stirred frequently, and apply with a spray pump. This will kill the eggs and young larvæ of the codling moth on apple and other fruits, and possibly may do so in this case. The great difficulty in this climate is that frequent showers wash off the poison, and it has to be repeated frequently. The Paris green can also be applied as a powder, mixed with flour or air-slaked lime, in the proportion of 1 part of Paris green to 100 of flour or lime. I would advise collecting all infected squashes and feeding to pigs or other animals or bury them so deep the fly can not get out when it hatches. If all who grow the crops which it breeds in would do so, I think it could be at least checked; the great difficulty would be to know if there is any wild fruit, etc., upon which it deposits its eggs for development. I have not observed it attacking anything but the cucumber, melon, and squash family.

"The following life history, which I have learned by experimenting in a 'hatchery,' may interest you, if you have not already determined the same for yourself. The fly which you describe is more like a small-sized botfly than a wasp, and will be seen hovering about the vines of muskmelons, squashes, etc., and when disturbed darts away very quickly, so rapid, in fact, one can scarcely follow it with the eye. It stings not only the fruit with its ovipositor, but also the young and tender growth of the vines, depositing a number of eggs, which soon hatch into small white maggots that feed on the tissues of the plant or fruit, causing it to decay. After the maggot has attained its growth, it descends into the soil, where it develops into a small chrysalis of a light yellowish-brown color, and in about ten or twelve days comes out a perfect insect, ready to repeat its mission of destruction. I do not know how many generations it will produce in a year, but in the warmer and drier districts I believe it will breed the year through, except possibly a while during the winter months, and then its development is only retarded by the cooler weather, which prevents the chrysalis maturing so rapidly.

"If you will take a squash or other specimen with the eggs or young maggots in the same, placing it in a box containing two or three inches of loose, dry soil, keeping it covered with a piece of glass, you can soon learn for yourself its life history, and perhaps make observations that may lead to means of successfully combating the pest.

"Yours, respectfully,

"BYRON O. CLARK,

"*Secretary and Commissioner of Agriculture.*"

The melon fly belongs to the family Trypetidæ and was described as new to science in 1899 by Mr. D. W. Coquillett, of the Bureau of Entomology, U. S. Department of Agriculture. Mr. Coquillett's description is as follows:[a]

A NEW TRYPETID FROM HAWAII.

Dacus curcurbitæ n. sp. Head light yellow, the occiput, except the sides and upper margin, reddish yellow, an ocellar black dot, front marked with a brown spot in front of its center and with three pairs of orbital brown dots, a black spot on each side of the face near the middle and a brown spot on the middle of each cheek; antennæ, palpi, and proboscis yellow, the latter mottled with brown. Thorax reddish yellow, the humeri, a median vitta on the posterior half of the mesonotum, another on each side above the insertion of the wings, uniting with an irregular band which extends upon the pleura to the upper part of the sternopleura, also a large spot on each side of the metanotum, encroaching upon the hypopleura, light yellow; scutellum, except its extreme base, light yellow, bearing two bristles. Abdomen light yellow on first two segments, reddish yellow on the others, the extreme base, a fascia at the bases of the second and third segments, usually a lateral spot on the fourth and fifth, also a dorsal vitta on the last three segments, blackish or brownish; first segment of the ovipositor of the female slightly longer than the fifth segment of the abdomen. Wings hyaline, the apex of the subcostal cell from a short distance in front of the apex of the auxiliary vein, the marginal and submarginal cells, the median third of the first basal cell and a large spot in upper outer corner of the first posterior cell, brown; anal cell brown, this color encroaching on the third posterior cell and bordering the sixth vein almost to its apex; posterior crossvein bordered with brown, this color extending to the hind margin of the wing; upper end of the small crossvein also bordered with brown. Halteres light yellow. Legs light yellow, the broad apices of the femora and the last four joints of the tarsi reddish yellow, hind tibiæ reddish yellow or dark brown. Length 6 to 8 mm.

Honolulu, Hawaii. Two males and two females bred by Mr. George Compere from the larvæ living in green cucumbers. Type No. 4207, U. S. Nat. Museum.

The food plants are, locally, all the members of the plant family Cucurbitaceæ (watermelons, muskmelons, cucumbers, squashes, pumpkins, etc., including a wild cucurbit, *Sycos* sp.); pods of beans; tomatoes; and the fly has been reported as infesting ripe fallen mangoes and the fruit of the papaya. Mr. F. W. Terry informs the writer that he bred *Dacus cucurbitæ* from larvæ infesting ripe mangoes during August, 1907.

The life history (see figure 3), covering a period of about three weeks, is as follows: The female by means of her strong ovipositor pierces the epidermis of the melon, or other host plant or fruit, and prepares just beneath the surface, in the tissue, an egg-chamber into which through the one incision or opening are deposited several eggs, the number varying from only 5 or 6 to as many as 15. A single fly may be responsible for many such incisions and usually "stings"

[a] Ent. News, 10 (1899), No. 5, pp. 129, 130.

the fruit several times. The flies are more active in oviposition in the early morning, remaining quiet during the middle of the day and especially on bright, sunny days hidden in the shelter of the vines or foliage about the field during the heat of the day. Observations on the attack of this pest on watermelons indicate that the very young melons are usually chosen for oviposition, presumably because the rind is more tender and capable of penetration. The larger proportion of the melons are infested from time of setting of the fruit until a size of about 3 inches in length is attained. The writer has visited fields where it has been practically impossible to find a melon of that size that was not egg-infested or contained developing larvæ. Larger melons have been found newly infested, but the incision in the varieties observed was near the more tender stem end. This is speaking only of watermelons. Undoubtedly muskmelons and cu-

FIG. 3.—Life cycle of the melon fly (*Dacus cucurbitæ*) : *a*, cluster of eggs, natural size; *b*, egg, enlarged; *c*, larva; *d*, puparium. Natural size of adult, larva, and pupa shown by lines. (Drawn for the author by Mr. W. E. Chambers.)

cumbers are capable of becoming infested much later in their development. In a field where the fly is epidemic, however, the larger melons as well contain the larvæ in all stages of development, the melons showing likewise all stages of decay. Since the enemy is an internal feeder, a correct estimate of the damage can not be obtained by a passing observation. Many melons perfect in shape upon being opened are found to be infested and sometimes completely rotted with the exception of the rind. In some instances the attack is resisted and the wound heals over, but the result is a deformed product, unfit for the market.

The vines as well as the fruit are infested. This is especially true if the growth is succulent. The vines are usually infested in the larger portions near the crown. During wet weather the decay of the fruit and vines progresses more rapidly than during dry

weather. In dry seasons the vines as a rule survive the attack and the wounded portions heal over.

After hatching from the egg the larvæ burrow on into the tissue of the melon, feeding entirely on the interior. When removed from the melon the larvæ have a peculiar mode of locomotion or possibly of protection. They double themselves together and then, suddenly straightening out, throw themselves into the air and quite a distance from the place they occupied. When fully developed the larvæ leave the infested melon or vine and enter the soil directly beneath, where at a distance of an inch or so from the surface they pupate.

No special natural enemies or checks to the melon fly have been observed in Hawaii. Regarding natural enemies Mr. Alexander Craw, superintendent of the division of entomology, board of agriculture and forestry, Hawaii, says:

> From dead specimens of the "melon fly" (*Dacus cucurbitæ*) received by this division from the government entomologists of India, we learn of the existence of several parasites that prevent its seldom or ever becoming a pest there. An effort should be made to introduce these parasites here by way of Hongkong. This would be a difficult experiment, owing to the great distance, but the undoubted benefit to the melon industry of this Territory, in case these parasites were successfully introduced and established, would justify the expenditure of considerable money in the attempt to control this pest.[a]

Prof. W. W. Froggatt, government entomologist of New South Wales, who is making an official trip around the world, recently visited Hawaii. One of the principal objects of his mission was in the interests of controlling the Queensland fruit fly (*Dacus tryoni*), a fly belonging to the same genus as our melon fly. Mr. Froggatt, in company with the writer, visited several districts in these islands where melons were growing, and detailed information on the fly and its occurrence in Hawaii were obtained by him. The writer is pleased to say that Mr. Froggatt will visit the countries of the Mediterranean and India before his return to Australia, and will carefully investigate any enemies of fruit flies in general that occur in those countries. If any special enemies of the group of flies to which our melon fly and the Queensland fruit fly belong are found they will be introduced and established in Australia and it will then be a comparatively easy matter to introduce them from that country into Hawaii. Mr. Froggatt is kindly keeping the writer informed of the progress of his trip, and much of interest to Hawaii will undoubtedly result.

The common preventive measure among the Japanese growers is to cover the young melons with a piece of gunny sack, paper, or some straw as soon as they set. When the melons have outgrown the protection of this covering, they are usually beyond the danger of an attack by the fly. It requires constant attention to cover the newly

[a] Hawaiian Forester and Agr., 4 (1907), No. 5, p. 113.

set melons before they are visited by the overindustrious fly. Protection could be secured by hand pollinating the flowers and covering them before the fruit is formed. There is a difference in the resistance of the different varieties of melons. The harder skinned varieties are less subject to injury, and it is well to select a hard-skinned melon for planting, even at a sacrifice of quality.

All infested melons and vines should be collected at regular intervals throughout the growth of the crop and either burned or buried. Burning is the most effective, but if the acreage is large, holes or pits can be dug at convenient distances through the field and all infested melons and vines collected at intervals of five or six days and deposited in the nearest pit. They should then be covered with earth to a depth of several inches. Overirrigation, producing succulent growth, favors infection of the vines.

After harvesting a crop all melons and vines left in the field should be collected and destroyed. If not done this refuse will breed swarms of the fly that will seek the products they infest in the surrounding district.

REFERENCES TO THE MELON FLY (DACUS CUCURBITÆ) IN HAWAII.

CLARK, B. O. The Hawaiian, Vol. I, No. 27, p. 6. Honolulu, 1898.
COQUILLETT, D. W. Ent. News, 10 (1899), No. 5, p. 129.
CRAW, ALEXANDER. Bien. Rpt. Bd. Hort. Cal., 8 (1901–2), p. 198.
———. Rpt. Bd. Comrs. Agr. and Forestry, Hawaii, 1 (1904), p. 138.
———. Hawaiian Forester and Agr., 4 (1907), No. 5, p. 113.
GRIMSHAW, P. H. Fauna Hawaiiensis. Cambridge, 1901, vol. 3, pt. 1, p. 45.
HOWARD, L. O. U. S. Dept. Agr., Div. Ent. Bul. 22, n. ser., 1900, p. 93.
———. Proc Ent. Soc. Washington, 4 (1901), No. 4, p. 490.
KOEBELE, A. Rpt. Comr. Agr. and Forestry, Hawaii, 1900, p. 39.
KRAUSS, F. G. Hawaiian Forester and Agr., 2 (1905), No. 11, p. 356.
PERKINS, R. C. L. Rpt. Governor Ter. Hawaii, 1902, p. 36.
SMITH, J. G. Annual Report of the Hawaii Agricultural Experiment Station for 1902. U. S. Dept. Agr., Office Expt. Stas. Rpt. 1902, p. 324.
———. Annual Report of the Hawaii Agricultural Experiment Station for 1903. U. S. Dept. Agr., Office Expt. Stas. Rpt. 1903, p. 417.
TERRY, F. W. Hawaiian Forester and Agr., 3 (1906), No. 2, p. 44.
VAN DINE, D. L. Hawaii Agr. Expt. Sta. Bul. 3, 1903, p. 7.
———. Annual Report of the Hawaii Agricultural Experiment Station for 1904. U. S. Dept. Agr., Office Expt. Stas. Rpt. 1904, p. 376.
———. Hawaiian Forester and Agr., 3 (1906), No. 4, pp. 127–129.

FLEAS.

Several outbreaks of fleas have occurred in Honolulu during the year. The writer dealt with two cases in residences and succeeded in controlling the pests. In each instance the species was the common dog and cat flea (*Ctenocephalus canis*).[a] The determination is by Mr.

[a] *Pulex serraticeps* is a synonym.

D. W. Coquillett, Bureau of Entomology, U. S. Department of Agriculture.

Mr. C. F. Baker gives the following in regard to the distribution and hosts of this species:

> The common cat and dog flea is probably the most widely distributed member of the order, occurring practically wherever cats and dogs occur. Doctor Lutz sends specimens from Brazil. It seems to be a normal and abundant parasite of cats and dogs, but has been found on a variety of other animals. It occurs commonly as a transient guest on almost all of the domesticated, semidomesticated, or caged animals, and will bite human beings whenever opportunity offers. Many reported cases of infestation of houses have been found to be due to this species, rather than to *Pulex irritans*. The case of a lot of fleas collected by Mr. Snyder from a fox at San Diego, Cal., offers a peculiar instance of unusual occurrence. A part of this lot proved to be *P. irritans* and the rest this species.[a]

The source of the fleas was traced to dogs about the dwellings, in one instance to homeless dogs that had taken up their abode beneath the house, and in the other to a dog belonging to the caretaker of the place. In the latter case when the family returned, after a considerable absence, they found the house, yard, and outbuildings infested with fleas. In and about Honolulu there are numbers of homeless dogs and cats that breed and distribute the pest wherever they roam.

Briefly the life cycle of the dog and cat flea is as follows: The eggs are laid loosely on the hairs of the dog or cat. These animals, when lying or walking around the place, leave behind innumerable eggs that become detached with the hairs in the persistent efforts of the animals to dislodge the adult fleas that are feeding on them. The eggs hatch and the larvæ develop in any place where the conditions of temperature and moisture are favorable. They feed during the larval period of life on whatever organic matter may be found in the places they occupy. These places may be in or beneath a rug or carpet in a house, in the dust of an unswept room, in crevices or joints of the underpinnings of the house, in the lawn beneath the grass, or in any of the outbuildings where the animals sleep.

In regard to the length of time necessary for development, Doctor Howard says:

> In the observations made at this Department upon this species of flea during the summer of 1895, some difficulty was found in preserving just the right degree of moisture to enable the insect successfully to transform. An excess of moisture was found prejudicial to the development of the species, as was too great dryness. The observations showed, however, that at Washington in summer an entire generation may develop in a little more than a fortnight. Hence

[a] A Revision of American Siphonaptera. Proc. U. S. Nat. Museum, 27 (1904), p. 384.

a housekeeper shutting up her house in June, for example, with a colony of fleas too small to be noticed inside it, need not be surprised to find the establishment overrun when she opens it up again in September or October.[a]

The following remedial measures were recommended:

(1) If the lawn is infested, cut the grass as close to the ground as possible and burn the refuse. Exposure to the air and sun will be detrimental to the development of the larvæ. Keep the lawn well watered.

(2) Clean out and burn all refuse from beneath the infested dwelling, leaving the surface of the ground as bare as possible, and apply an even dressing over the surface of lime, sulphur, and buhach at the rate of 20 pounds of air-slaked lime to 3 pounds of powdered sulphur and 1 pound of buhach, thoroughly mixed and dry. Spray the underpinnings of the house, and the drives and walks (if the latter are sand, gravel, or dirt), with kerosene emulsion at the rate of 1 part of stock solution of the emulsion to 10 parts of water.

(3) If dogs are owned, provide a room for them to sleep in and keep cats out of the house. Wash with strong, hot soapsuds the floors of the room where the dogs are to sleep, and sprinkle afterwards, when dry, with a liberal amount of buhach. Use a liberal amount of buhach in places where the dogs have been in the habit of sleeping and remove and burn from such places all refuse, old sacks, matting, etc. Every week or so take the dogs to the room provided for them and brush them thoroughly with a strong stiff brush. Afterwards collect the resulting hairs and the bedding and burn or immerse the sacks in hot soapsuds and hang in the sun to dry. Then wash the room out as before and sprinkle with buhach and return the bedding. The dogs should be washed regularly, a little creolin being added to the water.

(4) If the house is infested, sprinkle a liberal amount of buhach beneath all rugs and matting and under all shelving and cabinets. The following day take all rugs, carpets, and matting out of doors and shake thoroughly and hang in the sun for several hours. Wash the floors with hot soapsuds. Sprinkle buhach beneath the rugs, carpets, and matting when returning them to the house.

In one case treated the fleas were so numerous that the men engaged in the work of destruction were with difficulty held to their job. Finally in desperation the writer purchased a quantity of "fly-paper" and wrapped the legs of the laborers in this (sticky side out). Several thousand adult fleas were captured in this manner in a day's work, and the workmen were thus afforded a measure of protection.

[a] U. S. Dept. Agr., Div. Ent. Circ. 13. 2. ser., 1896, p. 4.

MOSQUITOES.

The top-minnows [a] introduced in 1905 to feed upon mosquito larvæ are established on all the principal islands. Areas of standing water are common in Hawaii and breed mosquitoes in immense numbers. (See Pl. I, fig. 1.) The following distribution of the fish has been made: Island of Oahu—Honolulu and vicinity generally, Aiea, Pearl City, Waialua, Maunawai, Wahiawa, and Waimanalo; island of Hawaii—Hilo and vicinity, and Paauhau; island of Maui—Kahului, Wailuku, and Lahaina; island of Kauai—Lihue, Eleele, and Waimea; and island of Molokai—Kalaupapa.

The history of the introduction of these fish has been summed up by the writer and published as Press Bulletin No. 20 of this station. It will be no longer necessary to breed the top-minnows for distribution, as the little fish swarm in several places where they have been liberated and can be obtained easily by those desiring to extend their distribution. This project is therefore completed. Hawaii has gained an addition to its fauna that will in future years many times repay the sum expended in the introduction and establishment of these natural enemies of mosquitoes.

The common Hawaiian mosquito, locally known as the "night" mosquito, previously reported by the writer as *Culex pipiens* [b] and by Mr. F. W. Terry as *C. fatigans*,[c] has been determined by Dr. H. G. Dyar as *C. cubensis*. One point of interest in regard to this species observed during the year is worthy of record. The larvæ have been found to breed in brackish water. To what extent can not be said without a careful survey. Waimanalo on the windward side of the island of Oahu has long been notorious as a mosquito-ridden place, and this is saying quite a little in Hawaii, where mosquitoes have been generally abundant. The main source of the mosquitoes was traced to a makai marsh, and an analysis of a sample of water from this marsh, taken at a place where mosquitoes of this species were breeding in immense numbers, gave 50 grains of salt to the gallon. (See Pl. I, fig. 2.)

In 1904 the writer pointed out the danger from yellow fever attending the establishment of a direct line of steamers between Hawaii and the Mexican coast and Panama.[d] The present discussion of this subject and its importance to the welfare of Hawaii leads the writer

[a] The species introduced were *Mollicnsia latipinna*, *Fundulus grandis*, and *Gambusia affinis* of the family Pœciliidæ. These fish were collected and transported to Hawaii from Seabrook, near Galveston, Tex., by Mr. Alvin Seale.

[b] Hawaii Expt. Sta. Bul. 6, 1904, pp. 14–21.

[c] A Preliminary Account of the Insects of Economic Importance in the Hawaiian Islands (Diptera). Hawaiian Forester and Agr., 3 (1906), No. 2, pp. 36, 37.

[d] Hawaii Expt. Sta. Bul. 6, 1904, pp. 22, 23.

FIG. 1.—STANDING WATER FROM RICE AND TARO FIELDS WHERE MINNOWS HAVE BEEN SUCCESSFULLY INTRODUCED.

FIG. 2.—MARSH AT WAIMANALO, ON WINDWARD SIDE OF OAHU, WHERE FORMERLY MOSQUITOES BRED ABUNDANTLY.

to reprint here an article by Prof. V. L. Kellogg. The article is as follows:

To the Editor of Science: The continuous discussion of Panama Canal affairs suggests to me to call attention to the possibility that the cutting of the canal may lead to trouble from yellow fever in two of our Pacific island colonies. In the summer of 1902, spent in the Hawaiian and Samoan Islands as agent of the U. S. Bureau of Fisheries, my attention was forcibly called to the unusual proportions of the mosquito plague in both these island groups. If it were not for the dragon flies which wage effective war against the "day mosquitoes," and for the bed canopies of netting which protect the sleeper from "night mosquitoes," life would hardly be tolerable in Honolulu. In Tutuila (our principal Samoan island) mosquitoes are the most obvious features of the above-water fauna aside from the brown natives themselves. Now both in Hawaii and Samoa one of the most abundant of the infesting mosquito species is *Stegomyia fasciata*, which is none other than the yellow-fever mosquito, that is, the particular mosquito species which harbors and disseminates, in yellow fever regions, the plasmodium or bacterium which is the immediate cause of the disease.

So far no cases of yellow fever have occurred in Hawaii or Samoa, but this is obviously not because of the absence of the yellow fever host, but, presumably, of the yellow fever specific causal agent, the pathogenic "germ." It is to be presumed that ships have not as yet carried yellow-fever-germ-infested specimens of Stegomyia from the West Indies to Hawaii or Samoa. Going around the Horn is probably an effective check to the spread of yellow fever from the West Indies to our Pacific Islands by reason both of the time required and the low temperatures met. Besides, there is little traffic now between the two regions. But with the cutting of the canal, making possible a direct short-time passage of ships from the Gulf of Mexico to Hawaii, or to Samoa, all of the voyage being within tropical or subtropical latitudes—the Hawaiian Islands are in 20° north latitude, the Samoan Islands in 14° south latitude—will there not be a real danger of planting the dread agent of yellow fever in our Pacific colonies in which already the necessary insect host exists in enormous numbers? There may be obvious reasons why this migration can not take place, but they are not apparent to me now. It is, at least, a contingency to be had in mind by those charged with the responsibility of public health affairs in Hawaii and Samoa.[a]

BEE KEEPING.

The principal line of work in bee keeping during the year has been the continuation and completion of the work on the source and characteristics of Hawaiian honeys, the assistant chemist of the station cooperating in a determination of the chemical composition of the same. This information has been prepared for publication as Bulletin No. 17 of this station. In all 54 samples of honey were collected and the source in each instance determined. Forty-nine of these samples were analyzed and a detailed study made of the two types represented—a floral honey and a honeydew honey.

The greatest value of this work has been its relation to marketing the Hawaiian product under the Federal Food and Drugs Act of June

[a] Science, n. ser., 23 (1906), No. 577, p. 114.

30, 1906. The bulk of the Hawaiian honey is of a type that has been little studied and, for this reason, was not considered in the official definition of honey. The type is decidedly abnormal under the present official definition of honey and its abnormal characteristics are due to the presence of honeydew, a saccharine substance secreted by certain leaf-sucking insects or secreted by the plant itself from special organs. In Hawaii the honeydew is derived by the honeybee mainly from the secretions of the sugar-cane leaf hopper and the sugar-cane aphis on the leaves of the sugar cane.

The problem confronting the Hawaiian bee keepers was presented by the writer in person to the proper officials at Washington. While no modification of the official standard of honey was obtained, the results of the investigations on the Hawaiian product by this station have been accepted by the experts having the work in charge as satisfactory and conclusive.

The Hawaiian honeys, while somewhat abnormal in their ash content, are recognized as natural products and are not considered as adulterated in the usual meaning of that term. All honeys that polarize to the left, and this includes the pure algeroba honey and many of those made by bees from floral nectar and other substances, will be recognized as pure natural products and may be marketed as such. Those that polarize to the right are to be given a distinctive label, and as they are largely composed of honeydew, it is suggested that they be labeled "honeydew honey." A statement can accompany the label on the honeydew package which may read as follows: "This is a natural product containing no added glucose or other added sugars. It is unadulterated and is a product gathered and stored by the honeybee."

The writer would here express his appreciation of the careful and detailed consideration given the subject during his stay in Washington by Dr. E. F. Phillips, in charge of apicultural investigations, Bureau of Entomology, and Dr. C. A. Browne, in charge of the sugar laboratory, Bureau of Chemistry.

Two further projects relating to bee keeping have developed from the work on Hawaiian honey. They are (1) the introduction and establishment of bee plants to increase the floral product and improve the character of Hawaiian honey, and (2) the production of beeswax on a commercial scale. The writer spent two weeks in southern California on his return home from Washington and gave special attention to plants desirable to introduce into Hawaii for bee pasturage. White sage, black sage, two species of Phacelia and horehound, abundant nectar producers and suitable for dry waste lands, will be introduced during the coming year. A list of some twenty other plants was obtained and other introductions will be made. Some of the plants are valuable as forage, but others must be studied to learn

whether or not there will be danger of their invading the pasture lands or cultivated areas. As regards wax production, wax is at present considered simply incidental to honey production. The writer believes it will be more profitable to Hawaiian bee keepers to increase the proportion of wax to honey and experiments will be undertaken with this in view. The experiments will include the feeding back of honey and modifications of the present methods of extraction and the use of foundation.

FOUL BROOD.

Neither European foul brood (*Bacillus alvei*) nor American foul brood (*B. larvæ*) has as yet become established in Hawaii. In order to prevent their introduction the Hawaiian Bee Keepers' Association was successful in obtaining the following legislation at the last session of the Territorial legislature:

AN ACT (ACT 69) To amend Chapter 28 of the Revised Laws of Hawaii by adding to said chapter a section to be known as Section 389A.

Be it enacted by the legislature of the Territory of Hawaii:

SECTION 1. Chapter 28 of the Revised Laws of Hawaii is hereby amended by adding a new section thereto to be known as Section 389A, and to read as follows:

"SECTION 389A. It shall be the duty of the board to make rules and regulations and to amend the same from time to time, in its discretion, subject to the approval of the governor, for and concerning the importation into the Territory of bees and for the preservation, protection, and improvement of bees now within the Territory, and for the quarantine, inspection, fumigation, disinfection, exclusion, or destruction, either upon importation into the Territory or at any time or place within the Territory, of any bees, and any box or other container and their contents in which bees have been imported or contained, which is or may be infested with or liable to assist in the transmission or dissemination of any insect or disease injurious to bees. All rules and regulations made as aforesaid shall have the force and effect of law. It shall be the duty of the board to establish an observational apiary, and all bees imported into the Territory shall be there quarantined, free of cost to the owners, until such time shall have elapsed as to enable the proper entomologist or inspector of the board to certify to the owners that such bees are clean and free from disease. The entomologists or inspectors of the board may enter upon the premises of any bee keeper for the purpose of inspecting the apiaries and of carrying out the orders of the board, and they shall not be holden guilty of any misdemeanor by so doing nor shall they be personally liable in damages, except for acts beyond the scope of their authority or due to their own negligence."

SEC. 2. This act shall take effect from and after the date of its approval.

Approved this 17th day of April, A. D. 1907.

G. R. CARTER,
Governor of the Territory of Hawaii.

SILK CULTURE.

The investigations relating to the possibility of silk culture have progressed far enough to enable the writer to state definitely that silk of good quality can be produced with as little effort in Hawaii

as in any silk-producing country. Three crops of cocoons have been grown, the details of which are given in the reports of the entomologist for 1905 and 1906, representing the Japanese white, the Chinese Oro yellow, and the Italian Sferici races, and these cocoons have been pronounced by the experts of the U. S. Department of Agriculture Bureau of Entomology "well worthy of being graded as first class." Doctor Howard also states that the economy in reeling "is equal to the most economical results obtained in experienced silk-producing countries." These results were obtained under abnormal and adverse conditions of food and equipment for growing the worms.

The 1906 experiments were all but ruined by a shortage of food at the most critical time, due to a drought that forced the mulberry trees into a semidormant state. The supply of mulberry leaves has heretofore been obtained from various trees and hedges growing in widely separated places in the city of Honolulu. To provide for future experiments and to obtain information on the culture of the mulberry for silk raising, a mulberry plantation has been established during the year. (See Pl. II.) This plantation is about 1 acre in extent, is provided with facilities and water for irrigation, and consists of 2,000 seedlings of *Morus alba*, received through Dr. L. O. Howard from the Bureau of Plant Industry.

Two systems of planting the mulberry have been tried. The seedlings were placed in orchard rows and in hedges. The plants in orchard rows will be allowed to grow to trees and will be pruned to produce the maximum amount of leaves. The hedges will be stripped of their leaves during feeding time and cut back after each picking. The extent that leaf production can be influenced by methods of culture and irrigation will be determined, together with the most profitable system of mulberry culture as regards labor for leaf picking. The project on silk culture will be limited during the coming year to the culture of the mulberry. The next experiment on the growing of cocoons will be undertaken on a more extended scale than heretofore; the abundant food supply close at hand will make this possible. If Hawaii is to succeed in holding the laboring class to the soil, the industry of silk culture is worthy of receiving serious consideration.

MULBERRY SEEDLINGS TEN MONTHS FROM TIME OF PLANTING.

A PARTIAL LIST OF THE INJURIOUS INSECTS OF HAWAII, PART 4.

(Continued from the Annual Report of the Hawaii Agricultural Experiment Station for 1906.)

FIELD CROPS.

RICE.

A beetle (*Rhizopertha pusilla*) was bred from stored rice that has been introduced for seed. This species is recorded by Blackburn from the island of Oahu in 1885.[a]

The Angoumois grain moth (*Sitotroga cerealella*) has been bred in large numbers from stored rice during the past year. The moth infests both harvested rice and standing rice in the field. The pest has proved especially persistent in stored rice in the paddy, but has been successfully controlled at the station by carbon bisulphid. The fact that this pest can breed uninterruptedly throughout the year in Hawaii will necessitate prompt remedial measures when infestation occurs to prevent a heavy loss in weight.

In regard to a remedy, Chittenden says:[b]

> A limited number of insects, like the Angoumois grain moth in the extreme South, enter the grain in the field, and certain precautions are therefore necessary to prevent their access to the granary. This is accomplished (1) by harvesting as soon as the grain is ripe, and (2) by thrashing as soon afterwards as possible.
>
> In the process of thrashing or cleaning much infested grain is blown out with the chaff and dust, and the moths are killed by the agitation which the grain receives; but the immature forms of these insects, concealed in the kernels as eggs, larvæ, and pupæ, are apt to survive this treatment, and further measures are necessary for their destruction.
>
> For this purpose a quarantine bin is desirable, to be as nearly air-tight as possible, in which the newly thrashed as well as the infested or suspected grain can be fumigated with bisulphid of carbon. * * *
>
> Fresh grain should not be exposed to insect attack by being placed in bins with "weeviled" grain, or even housed under the same roof with such grain. If before storing in buildings that have been infested the old grain be removed, the bins thoroughly cleaned, floors, walls, and ceilings brushed and scrubbed, the chances of infestation will be reduced to a minimum. If the storehouse has been badly infested a fumigation with bisulphid is necessary.

SWEET POTATO.

The sweet-potato weevil (*Cylas formicarius*). (See pages 28–30.)

The sweet-potato sphinx moth (*Protoparce cingulata*). The caterpillar of this moth (*Sphinx convolvuli*) is recorded by Meyrick, in Fauna Hawaiiensis, in 1899, from the islands of Hawaii and Maui.

---

[a] The determinations of the Coleoptera (beetles) recorded in this report were made by Mr. E. A. Schwarz, of the Bureau of Entomology, U. S. Department of Agriculture.

[b] U. S. Dept. Agr., Farmers' Bul. 45, pp. 19, 20.

The writer has collected specimens from the islands of Oahu and Molokai. The caterpillars are common on sweet-potato vines and *Ipomœa* spp.

The sweet-potato vine borer (*Omphisa anastomosalis*). The writer has not observed the work of this moth, but the species is recorded by Meyrick in Fauna Hawaiiensis in 1904. Mr. O. H. Swezey has observed the moth and the work of the caterpillars in sweet-potato vines and records his observations as follows:

> This Indo-Malayan moth was first recorded for Honolulu in 1904. Since then it has no doubt been on the increase, and may possibly before long become a garden pest, if not so already. During January, February, and March, 1906, I found the larvæ boring in vines of sweet potato in my garden. Of about half a dozen hills, all were found to be infested. The larvæ were found boring in the vines near the base, and hence just at the place to be the most injurious. Often two or more near together in the same vine, living upon the green, juicy pith of the stem. They probably do considerable boring in the potatoes also, as one was found in a potato from the market.[a]

The root maggot (*Pegomya fusciceps*) was collected on the island of Molokai during March, 1907. This insect pest is known commonly under various names, as the seed-corn maggot, the cabbage-root maggot, etc. Chittenden records the species as a pest of sweet potatoes.[b]

FRUIT CROPS.

PINEAPPLE.

The common mealy bug (*Pseudococcus citri*)[c] was recorded in the writer's report for 1904 as *Dactylopius* sp. The species is recorded by Kirkaldy in Fauna Hawaiiensis in 1902 from orange.

The pomace fly (*Drosophila ampelophila*). The determination of this fly was made by Mr. D. W. Coquillett, of the Bureau of Entomology, from specimens collected by the writer on July 19, 1906, found developing in ripe pineapples in canneries at Wahiawa, Oahu. This fly is common throughout the United States and particularly noticeable in the fall of the year about cider mills and wineries, about which it breeds in the pomace and refuse. No evidence of the work of the fly could be found in the field and apparently its injury is confined to the overripe and bruised pineapples in the cannery. Destruction of the waste about the cannery is an effective method of control.

---

[a] Proc. Hawaiian Ent. Soc., 1 (1906), pt. 2, p. 76.

[b] U. S. Dept. Agr., Div. Ent. Bul. 43, 1903, p. 69.

[c] The determinations of the Coccidæ (scale insects) recorded in this report were made by Mr. J. G. Sanders, Bureau of Entomology, U. S. Department of Agriculture.

MANGO.

Trionymus americanus, a small mealy-bug-like coccid, was collected from the bark of the Bombay mango by Mr. Donald McIntyre at Moanalua, Oahu, during July, 1906.

Thrips (Thripidæ, undetermined). Thrips were first noticed on the leaves of mangoes during 1906 at Moanalua, Oahu. During the summer of 1907 the insect had increased to injurious numbers in this locality and specimens were recently collected and referred to the Bureau of Entomology for identification. The insect is causing serious injury to the young growth of the trees and on badly infested trees blemishes the surface of the developing fruit. The most effective remedy thus far has proved to be a spraying mixture of whale-oil soap and tobacco prepared as follows: Five pounds of waste tobacco was boiled in sufficient water to make about 1 gallon of strong decoction. Two pounds of whale-oil soap was dissolved in 1 gallon of boiling water and then mixed with the tobacco decoction. The mixture was diluted with 10 gallons of water and applied as a spray.

APPLE.

The following insects have been collected from apple trees: The Japanese beetle (*Adoretus umbrosus tenuimaculatus*) and the scale insect (*Pseudaonidia clavigera*), collected in September, 1906, from apple at Koloa, Kauai.

ORANGE.

The scale *Parlatoria ziziphus* was taken from orange in January, 1907.

BANANA.

The banana leaf-roller was recorded in the 1904 report of the writer as *Omiodes blackburni*. Mr. O. H. Swezey, in a recent bulletin of the Hawaiian Sugar Planters' Experiment Station,[a] distinguishes the species infesting the banana from the common *O. blackburni* found on palms and describes the species infesting the banana as new under the name of *O. meyricki*.

COCOANUT.

The following insects have been observed working on the cocoanut palm tree: The cane borer (*Sphenophorus obscurus*), the palm leaf-roller (*Omiodes blackburni*), and the Florida red scale (*Chrysomphalus ficus*).

[a] Hawaiian Sugar Planters' Expt. Sta., Div. Ent. Bul. 5, pp. 24–27. (August, 1907.)

ORNAMENTAL PLANTS.

HIBISCUS.

Cosmophila sabulifera. The caterpillars of this moth were destructive to the foliage of hibiscus about Honolulu in one or two instances during the year. The moth was determined by Doctor Dyar, of the U. S. National Museum. The species is recorded by Meyrick in 1899 in Fauna Hawaiiensis, from Hawaii, Kauai, and Oahu.

PEPPER TREE.

The following scale insects have been collected during the year from the pepper tree: *Saissetia nigra* and *Aspidiotus lataniæ.*

ROSE.

The common aphis of the rose in Hawaii has been determined and recorded during the year as *Macrosiphum rosæ* by Mr. Kirkaldy.[a]

BAMBOO.

A scale insect (*Asterolecanium miliaris*) was collected from bamboo on Kauai in October, 1906.

FOREST TREES.

RUBBER (CEARA).

The following scale insects were collected from Ceara rubber during the year: *Aspidiotus cyanophylli* and *Saissetia oleæ.*

Wireworms, larvæ of a click beetle (Elateridæ, undetermined), did some damage to seeds in seed beds in Nahiku, Maui, at the beginning of the planting there. The seeds had been filed through at the ends, allowing entrance by the worms. The source of the wireworms was found to be horse manure used in preparing the seed beds, the manure offering a breeding place to the beetles.

A bark beetle (*Xyleborus affinis*) and a snout beetle (*Pseudolus longulus*) were found to infest this tree, their attack being in the unhealed wounds caused by repeated tapping.

ALGEROBA.

The scale insect (*Asterolecanium pustulans*) was taken during the year from the algeroba on the islands of Oahu, Kauai, and Molokai.

WILD GUAVA (WAIAWI).

A bark beetle (*Xyleborus affinis*), Kauai, and the scale insect (*Aspidiotus lataniæ*), also from Kauai.

---

[a] Proc. Hawaiian Ent. Soc., 1 (1907), pt. 3, p. 100.

LIVE STOCK.

A considerable portion of the writer's time during the latter part of the year has been occupied in a study of the insects affecting live stock in Hawaii. The species affecting live stock that have been observed or are recorded from Hawaii will be briefly listed here, since a detailed report is in course of preparation.

CATTLE.

The horn fly (*Hæmatobia serrata*)[a] was probably introduced during 1897 and first recorded by Koebele in 1899. It also attacks sheep in Hawaii and to some extent horses.

The warble fly and the heel fly, *Hypoderma bovis* and *H. lineata*. One and possibly both of these flies have been brought to Hawaii with imported cattle from the western coast of the mainland. Neither species has apparently become established.

SHEEP.

The blow fly (*Calliphora dux*) occurs on the islands of Hawaii, Kauai, Oahu, and Molokai. This species is the abundant and injurious blow fly of the Hawaiian Islands.

The English bluebottle fly (*Lucilia serricata*). This animal parasite was taken in small numbers in company with the blow fly (*Calliphora dux*).

The American bluebottle fly (*L. cæsar*). This fly is recorded from the island of Hawaii by Grimshaw in Fauna Hawaiiensis in 1901.

The flesh flies (*Sarcophaga barbata* and *S. pallinervis*). Both of these species have been bred from dead animal tissue and would probably attack wounds in live stock.

The sheep bot fly or head maggot (*Œstrus ovis*). Recorded by Grimshaw in Fauna Hawaiiensis in 1901 from the island of Kauai.

The screw worm (*Compsomyia macellaria*). Reported from the island of Niihau during 1905.

HORSES.

The stable fly (*Stomoxys calcitrans*).

The horse bot fly (*Gastrophilus equi*).

The horse chin fly (*G. nasalis*).

The "night" mosquito (*Culex cubensis*).

[a] The determinations of the Diptera (flies) mentioned in this report were made by Mr. D. W. Coquillett, of the Bureau of Entomology, U. S. Department of Agriculture.

POULTRY.

Lice, undetermined.
Mites, undetermined.
The "night" mosquito (*C. cubensis*).

DOGS.

The dog flea (*Ctenocephalus canis*) (see page 35), the dog tick (*Rhipicephalus sanguineus*), and the "night" mosquito (*C. cubensis*).

STORED PRODUCTS.

A beetle (*Silvanus mercator*) was bred during the year from crackers and a prepared "breakfast food."

The ham and cheese maggot (*Piophila casei*) was collected during the year on the island of Molokai.

The cadelle (*Tenebroides mauritanica*) was bred in immense numbers from horse feed (rolled barley) in August, 1907.

A beetle (*Araeocerus fasciculatus*) was bred from the seeds of St. John's bread (*Ceratonia siliqua*) received from Kohala, island of Hawaii. This same beetle was bred from cotton bolls received from Kona, island of Hawaii.

A weevil (*Calandra linearis*) was bred from imported seeds of the sweet tamarind. Blackburn records *C. linearis striata* in 1885 as "plentiful in decaying tamarinds, near Honolulu."

ACCESSIONS TO ENTOMOLOGICAL LIBRARY RELATING TO HAWAIIAN ENTOMOLOGY.

(Continued from Report of the Entomologist, Annual Report of the Hawaii Agricultural Experiment Station for 1906, pp. 31, 32.)

CLARKE, W. T. The potato-worm in California. California Expt. Sta. Bul. 135, 1901, p. 5.

COBB, N. A. Fungus maladies of the sugar cane. (Relation of insects to Ithyphallus.) Hawaiian Sugar Planters' Expt. Sta., Div. Path. and Phys. Bul. 5, 1906, pp. 49–72, 90, 91.

———. Notes on some diseases of the pineapple. (Thielaviopsis and flies.) Hawaiian Forester and Agr., 4 (1907), No. 5, pp. 132–139.

CRAW, ALEXANDER. Report of the superintendent of entomology. Hawaiian Forester and Agr., 3 (1906), Nos. 10, pp. 322, 323; 11, pp. 330–332; 4 (1907), Nos. 5, pp. 113–116; 6, pp. 176–178; 7, pp. 208, 209.

———. Report of the superintendent of entomology and inspector. Rpt. Bd. Comrs. Agr. and Forestry, Hawaii, 3 (1906), pp. 138–158, figs. 7. (February 28, 1907.)

DOLE, S. B. Commerce (honey). Rpt. Governor Ter. Hawaii, 1902, pp. 12–14.

———. Sugar (cane-borer and leaf-hopper). Rpt. Governor Ter. Hawaii, 1902, p. 26.

FROGGATT, W. W. Domestic insects: Mosquitoes. Dept. Agr., N. S. Wales, Misc. Pub. 911, 1905, p. 3.

GIFFARD, W. M. Breeding experiments and some observations on the life history of *Rhyncogonus blackburni*. Proc. Hawaiian Ent. Soc., 1 (1907), pt. 4, pp. 127–129, pl. 1.

HIGGINS, J. E. Marketing Hawaiian fruits. Hawaii Expt. Sta. Bul. 14, 1907, p. 39.

———. Report of horticulturist. Hawaii Expt. Sta. Rpt. 1906, p. 33. (Washington, 1907.)

JUDD, A. F. The live-stock industry (horn fly). Rpt. Governor Ter. Hawaii, 1904, p. 123.

KELLOGG, V. L. Science and the fruit grower. Rpt. Fruit Growers' Conv. Cal., 31 (1905), pp. 127–129.

KIRKALDY, G. W., and SWEZEY, O. H. Proceedings of the Hawaiian Entomological Society, 1 (1906), pt. 2, pp. 42; 1 (1907), pts. 3, pp. 31; 4, pp. 51, illus.

———. Leaf-hoppers—Supplement (Hemiptera). Hawaiian Sugar Planters' Expt. Sta., Div. Ent. Bul. 3, pp. 186, index, pl. 20. (Sept. 2, 1907.)

———. Leaf-hoppers. Hawaiian Sugar Planters' Expt. Sta., Div. Ent. Bul. 4, pp. 60–66. (May 1, 1907.)

———. On some peregrine Aphidæ in Oahu. Proc. Hawaiian Ent. Soc., 1 (1907), pt. 3, pp. 99–103.

———. The literature of 1906 dealing with Hawaiian entomology. Proc. Hawaiian Ent. Soc., 1 (1907), pt. 3, pp. 107–109.

———. A catalogue of the hemipterous family Aleyrodidæ. Bd. Comrs. Agr. and Forestry, Hawaii, Div. Ent. Bul. 2, pp. 1–192. (Sept. 16, 1907.)

———. A note on the introduction of *Culcx fatigans* into the Hawaiian Islands. Proc. Hawaiian Ent. Soc., 1 (1907), pt. 4, p. 121.

———. Biological notes on the Hemiptera of the Hawaiian Isles No. 1. Proc. Hawaiian Ent. Soc., 1 (1907), pt. 4, pp. 135–161, illus.

KOEBELE, A. Rpt. Bd. Comrs. Agr. and Forestry, Hawaii, 3 (1906), pp. 159–164. (Feb. 28, 1907.)

KOTINSKY, J. Preliminary note on lantana insects in Hawaii. Proc. Hawaiian Live Stock Breeders' Assoc., 1905, pp. 69–78, figs. 8.

———. Horn-fly and its parasites in Hawaii. Proc. Hawaiian Live Stock Breeders' Assoc., 1905, pp. 78–82, figs. 2.

———. Parasite of an orthopterous egg. Proc. Hawaiian Ent. Soc., 1 (1906), pt. 2, p. 59.

———. History of economic entomology in Hawaii. Proc. 18th An. Meeting Assoc. Econ. Ent., U. S. Dept. Agr., Bur. Ent. Bul. 60, 1906, pp. 58–66.

———. Entomological notes. Hawaiian Forester and Agr., 3 (1906), No. 10, pp. 319–321; 4 (1907), Nos. 3, pp. 52–53; 4, pp. 77–80; 5, pp. 110–112; 9, pp. 281–283.

———. *Tribolium ferrugineum*, an enemy of *Megachila palmarum* Perkins. Proc. Hawaiian Ent. Soc., 1 (1907), pt. 3, p. 85.

———. Review of entomological literature. Hawaiian Forester and Agr., 4 (1907), No. 9, pp. 271, 272.

———. Aleyrodidæ of Hawaii and Fiji, with descriptions of new species. Bd. Comrs. Agr. and Forestry, Hawaii, Div. Ent. Bul. 2, pt. 8, pp. 93–101, pl. 1. (Sept. 16, 1907.)

KRAUSS, F. G. Preliminary report on rice investigations. Hawaii Expt. Sta. Press Bul. 19, 1907, pp. 6, 7.

MUIR, F. Notes on some Fijian insects. Hawaiian Sugar Planters' Expt. Sta., Div. Ent. Bul. 2, pp. 11, pl. 1. (Nov. 10, 1906.)

NORGAARD, V. A. Report of the territorial veterinarian (Horn-fly and screw-worm fly). Proc. Hawaiian Live Stock Breeders' Assoc., 1905, pp. 52–59.

PERKINS, R. C. L. The insects of Tantalus (Oahu). Proc. Hawaiian Ent. Soc., 1 (1906), pt. 2, pp. 38–51.

———. A new method of relaxing and cleaning specimens. Proc. Hawaiian Ent. Soc., 1 (1906), pt. 2, p. 52.

———. Notes on Hawaiian wasps with descriptions of new species. Proc. Hawaiian Ent. Soc., 1 (1906), pt. 2, pp. 61–74.

———. Tomocera, a genus of scale-bug parasite, with description of new species. Proc. Hawaiian Ent. Soc., 1 (1906), pt. 2, pp. 75, 76.

———. Parasites of leaf-hoppers. Hawaiian Sugar Planters' Expt. Sta., Div. Ent. Bul. 4, pp. 1–59. (May 1, 1907.)

———. On a species of Proterhinus from Samoa. Proc. Hawaiian Ent. Soc., 1 (1907), pt. 3, p. 87.

———. Insects at Kilauea, Hawaii. Proc. Hawaiian Ent. Soc., 1 (1907), pt. 3, pp. 89–99.

———. Notes on Hawaiian aculeate Hymenoptera. Proc. Hawaiian Ent. Soc., 1 (1907), pt. 4, pp. 111–113.

———. *Melittobia hawaiiensis* n. sp. Proc. Hawaiian Ent. Soc., 1 (1907), pt. 4, pp. 124, 125.

———. Supplementary notes on *Rhyncogonus blackburni* and its parasites. Proc. Hawaiian Ent. Soc., 1 (1907), pt. 4, pp. 130–134, illus.

PINKHAM, L. E. Health conditions of the Territory (mosquitoes). Rpt. Governor Ter. Hawaii, 1904, p. 27.

SMITH, J. G. The Hawaii Experiment Station. Hawaii Expt. Sta. Press Bul. 18, 1906, pp. 8–11.

———. Entomological investigations. Hawaii Expt. Sta. Rpt. 1906, pp. 16, 17. (Washington, 1907.)

STACKABLE, E. R. The commerce of Hawaii (honey). Rpt. Governor Ter. Hawaii, 1904, p. 131.

SWEZEY, O. H. *Rhyparobia maderæ*. Proc. Hawaiian Ent. Soc., 1 (1906), pt. 2, pp. 37, 38.

———. Life history notes and observations on three common moths. Proc. Hawaiian Ent. Soc., 1 (1906), pt. 2, p. 53–58.

———. The sweet-potato vine borer (*Omphisa anastomosalis*). Proc. Hawaiian Ent. Soc., 1 (1906), pt. 2, pp. 76, 77.

———. Observations on the life-history of *Oliarus koanoa* Kirkaldy. Proc. Hawaiian Ent. Soc., 1 (1907), pt. 3, pp. 83, 84.

———. An extraordinary leaf-hopper from Mt. Konahuanui, Oahu. Proc. Hawaiian Ent. Soc., 1 (1907), pt. 3, pp. 104–106.

———. Life-history and notes on the pink-winged Tryxalid (*Atractomorpha crenaticeps* Blanchard. Proc. Hawaiian Ent. Soc., 1 (1907), pt. 3, pp. 106, 107.

———. The sugar-cane leaf-roller (*Omiodes accepta*) with an account of allied species and natural enemies. Hawaiian Sugar Planters' Expt. Sta., Div. Ent. Bul. 5, pp. 60, pls. 6. (Aug. 20, 1907.)

———. Notes on *Sphinx convolvuli*. Proc. Hawaiian Ent. Soc., 1 (1907), pt. 4, p. 114.

———. Observations on recent swarms of caterpillars at Kaimuki (Oahu). Proc. Hawaiian Ent. Soc., 1 (1907), pt. 4, pp. 118, 119.

———. Odynerus parasites. Proc. Hawaiian Ent. Soc., 1 (1907), pt. 4, pp. 121–123.

———. An Omiodes egg-parasite (*Trichogramma prestiosa* Riley). Proc. Hawaiian Ent. Soc., 1 (1907), pt. 4, pp. 125, 126.

SWEZEY, Mrs. O. H. Observations on the life-history of Psychodidæ or moth-flies. Proc. Hawaiian Ent. Soc., 1 (1907), pt. 4, pp. 116–118.

TERRY, F. W. The increase of the antennal segments in certain Forficulidæ. Proc. Hawaiian Ent. Soc., 1 (1906), pt. 2, pp. 58, 59.

VAN DINE, D. L. Horticultural insect enemies. Hawaiian Forester and Agr., 3 (1906), No. 11, pp. 341–350.

———. Notes on *Cryptorhynchus mangiferæ* Fabr. (the mango weevil). Proc. Hawaiian Ent. Soc., 1 (1907), pt. 3, p. 79–82.

———. The introduction of top-minnows (natural enemies of mosquitoes) into the Hawaiian Islands. Hawaii Expt. Sta. Press Bul. 20, pp. 10, figs. 3. (July 25, 1907.)

———. Report of the entomologist. Hawaii Expt. Sta. Rpt. 1906, pp. 18–32. (Washington, 1907.)

REPORT OF THE HORTICULTURIST.

By J. Edgar Higgins.

The chief work of the year in the horticultural division has consisted in experiments in the shipping of tropical fruits. The horticulturist sailed from Honolulu August 1, 1906, accompanying a shipment of fruits composed of pineapples, avocados, papaias, and bananas. Arriving at San Francisco August 7, the whole shipment of fruit, except the bananas, was transferred immediately to express cars and taken to Portland, Oreg. From this point the fruit was distributed to Astoria, Tacoma, Seattle, and Vancouver, British Columbia. The results of these experiments, so far as the possibility of fruit shipping is concerned, and the methods best suited to shipping are embodied in a bulletin of this station.[a] It may be said here, however, that the experiments led to the belief that it is perfectly feasible to ship avocados and papaias to any market on the Pacific coast which can be reached by a direct journey; and pineapples and bananas may be shipped much farther. A large portion of the shipment, even of papaias and avocados, arrived in Portland in good condition, and specimens of each of these were taken to all the points mentioned. Specimen packages of pineapples were successfully shipped from Portland to the governors and the mayors of cities in all the chief mountain States.

The following letter from Governor Gooding, of Idaho, and the excerpt from a letter of Mr. G. B. Dennis, chairman of the publicity committee of the Chamber of Commerce of Spokane, Wash., will indicate something of the condition in which these fruits arrived, and the market which they would find in any part of this region.

State of Idaho, Executive Office,
Boise, Idaho, August 31, 1906.

Jared G. Smith, *Special Agent Hawaii Experiment Station,*
U. S. Department of Agriculture, Honolulu, Hawaii.

My Dear Sir: Your crate of fruit, which you very kindly sent me, was received about two days ago in the very finest possible condition. I want to thank you and the Hawaii promotion committee for your kindness, and to assure you that if you are able to deliver as fine fruit as this there should be no difficulty in securing a market throughout the United States for your product.

I have the honor to remain yours, very truly,

F. R. Gooding, *Governor.*

---

[a] Hawaii Sta. Bul. 14.

SPOKANE, WASH., *August 24, 1906.*

MR. JARED G. SMITH,

Special Agent in Charge, Hawaii Experiment Station, Honolulu, T. H.

DEAR SIR: I am the recipient of your twofold compliment—your letter of July 26, and the crate of pineapples received by express the day before, and assure you that I accept the compliments of the Hawaii Experiment Station and the Hawaii promotion committee very gratefully.

The pineapples were received in perfect condition, there not being a single blemish anywhere on any of them. It was my pleasure to eat one of them, and to distribute the other five among the members of my committee, all of whom gave high praise to the delicious taste and flavor of the fruit. I personally have no hesitancy in stating that these features of the fruit, as well as that of size, exceed those of the fruit that we are used to receive here from southern California, Mexico, and Florida, and there should be no reason why the Hawaiian Islands should not command this trade with this northwestern section of the United States.

Very truly yours,

G. B. DENNIS.

Chairman, Publicity Committee, Chamber of Commerce.

The Pacific Northwest is a market which Hawaiian fruit growers should seek to develop. With the direct communication which is bound to come sooner or later this will be one of our nearest markets. It is also the most remote market in the United States from the standpoint of Hawaii's competitors in tropical fruit growing in Florida, the West Indies, and Central America. It is so situated that from these points a long haul by rail is unavoidable. Hawaii even at the present time can reach this market by water route exclusively. The Pacific Northwest has a large and growing population. There is probably no part of the United States which is making as rapid strides in prosperity and in increase of a desirable class of population. The three cities of Portland, Seattle, and Tacoma in themselves represent nearly half a million people of a class that can afford to spend money freely for Hawaiian fruits. The whole surrounding country tributary to these cities is rich in agriculture, lumbering, and other resources, and is destined to become the center of a very large population. The same may be said of Western Canada, toward which the streams of population have been flowing rapidly for several years. Both these great sections of country, while rich in agricultural resources, can not grow either tropical or even subtropical fruits, and therefore offer a most inviting field for the sale of Hawaiian fruits.

This is emphatically the time to get into these markets and gain a foothold before competitors become so firmly established as to make entrance difficult for the Hawaiian growers.

ORCHARD AND OTHER FRUITS.

During the year the orchard area has been increased by the planting of about 4 or 5 acres. The first planting of avocados has made an excellent growth and should come into bearing in about two years hence. The orchard has been increased in area. A planting of mangoes, consisting of several hundred trees, some of which are inarched and others of which are to be budded, adjoins the orchard of avocados. The other newer plantings in orchard form consist of the following: Oranges (Pl. III, fig. 1), pomelos, lemons, papaias, sweet sop (*Anona squamosa*), sour sop (*A. muricata*), cherimoya (*A. cherimolia*), Kafir plum (*Harpephyllum caffrum*), *Spondius lutea*, guava (*Psidium guajava*), in several varieties, and the star apple (*Chrysophyllum cainito*). About 1 acre has been planted to mulberries, for experiments in the production of food for silkworms, in cooperation with the entomologist.

THE STAR APPLE.

The star apple (*Chrysophyllum cainito*) (Pl. III, fig. 2) is a fruit worthy of much wider cultivation than it receives. There are, in fact, comparatively few specimens of this tree in Hawaii, but sufficient have been grown to show its possibilities. It makes a strong growth, attaining a height of about 25 feet, and is one of the most beautiful fruit trees of small size, the under surface of the leaves being of a rich golden hue. The fruit is about the size of an apple, and when cut in cross sections shows the carpels so arranged as to simulate a star, thus giving the common name to the species. The fruit is globular in form and smooth, varying in color from green to purple. The pulp is of delicious flavor and pleasing texture and should place this fruit with the mangosteen in quality. All the varieties grown in Hawaii are seedlings, but it is highly probable that the tree could be propagated by budding or grafting, and thus perpetuate individual characters of the best varieties.

A few specimens of the star apple have already been planted in the station orchards and are prospering. About 150 seedlings are in the propagating houses and will be set in the orchard and distributed to local growers.

THE ANONA GROUP.

Several species of Anona are found in the gardens of a few cultivators in Hawaii, and at least one species, the cherimoya (*Anona cherimolia*), is found practically wild in Kona, Hawaii, where it has escaped from cultivation. The finer varieties of cherimoya are among the most highly prized of tropical fruits. These are propagated by grafting. The fruit weighs from 3 to 8 pounds, or even as high as

FIG. 1.—AN UNNAMED HAWAIIAN SEEDLING ORANGE.

FIG. 2.—THE STAR APPLE (CHRYSOPHYLLUM CAINITO).

FIG. 1.—THE SOUR SOP (ANONA MURICATA).

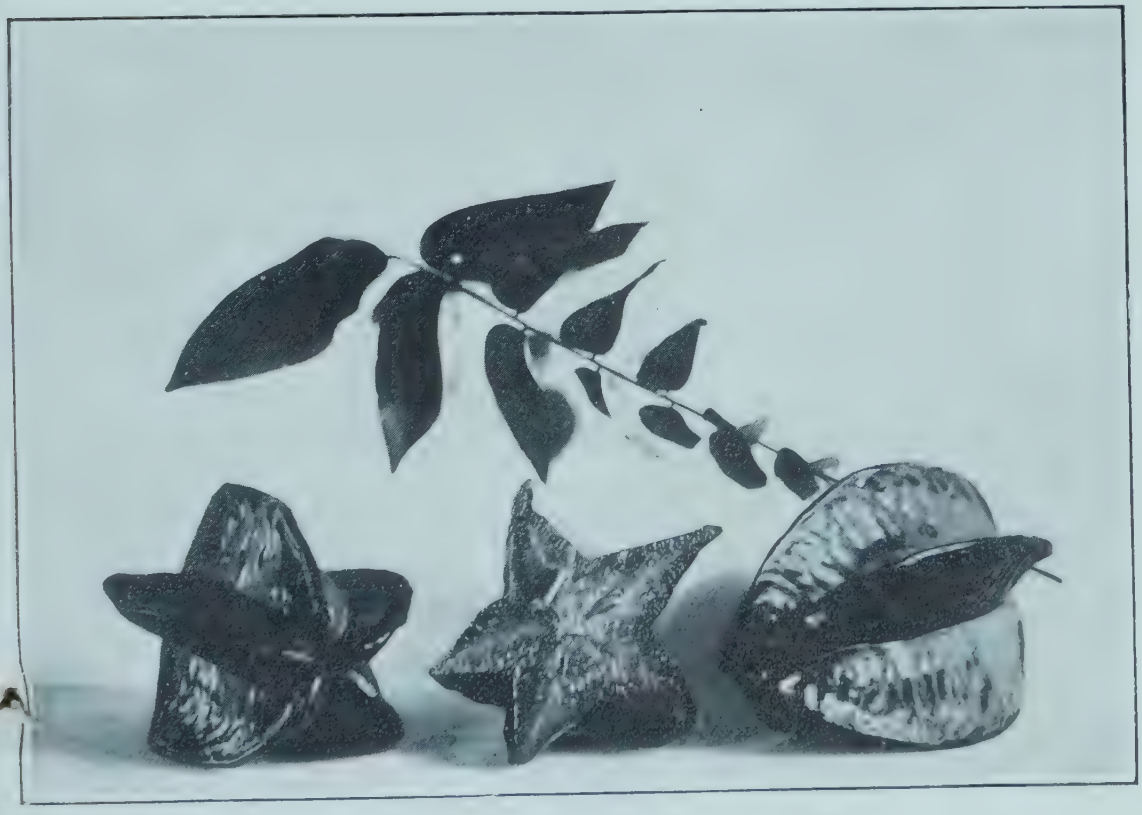


FIG. 2.—THE CARAMBOLA (AVERRHOA CARAMBOLA).

16. Those of ordinary size are reported to sell in the London market at $1.50 each, and the very large ones as high as $2.50 and even $3. This fruit is regularly cultivated in Madeira, and has replaced the grapevine in some parts of the island. From the luxuriant growth which the semiwild plants have made on the slopes of Kona, there is every reason to believe that, with the direct communication between Kona and the mainland which is likely to be inaugurated in the not distant future, the finer varieties of this fruit could be made highly profitable in cultivation. In the sheltered spots at some elevations on the island of Oahu this fruit could probably be grown and marketed in San Francisco. It is said to be a fairly good shipper. The station has already secured a few specimens of valuable varieties of cherimoya. The sweet sop (*A. squamosa*) should also be cultivated more extensively than at present, at least for home consumption. It is a very delicious fruit, though somewhat smaller than the cherimoya. The white flesh surrounds the large black seeds, but is easily separable from them. In form the fruit is heart shaped with an exterior divided into many segments. The sour sop (*A. muricata*) (Pl. IV, fig. 1) is perhaps the most vigorous stock of the Anonas in Honolulu. It appears to be better adapted to low elevations than some of the other members of the group. The fruit is not so universally appreciated as the cherimoya or the sweet sop, but is much liked by some, and is more commonly seen in the market in Honolulu than any other Anona. The pulp is eaten raw or may be used in sherbets.

THE CARAMBOLA.

The carambola (*Averrhoa carambola*) is a Chinese fruit of considerable value. The tree is of beautiful foliage and attains a height of about 20 feet. The fruits are produced abundantly and with their unique form and attractive coloring add much to the beauty of the tree. These fruits (Pl. IV, fig. 2) are deep lobed and star shaped in cross section. They contain an abundance of juice, which may be used in the making of a drink similar to lemonade. There is an acid and also a sweet variety. The station has about 150 seedlings of this also, which will be distributed in part and in part planted in the station orchard.

CARICA QUERCIFOLIA.

This species of Carica is said to be much richer in papaine, or "vegetable pepsin," than the papaia. Several trees of this species have been grown on the station trial grounds and have made a vigorous growth and produced their small fruits abundantly. No tests have

been made of the papaine content. The fruits have a slightly acid taste not found in the papaia, offering an interesting field for cross-breeding.

THE ROSELLE.

The cultivation of the roselle (*Hibiscus sabdariffa*) has been continued during the year. In November and December most of the crop was harvested.

This plant was first introduced in Hawaii from Australia, so far as the writer is informed, by Mr. R. A. Jordan. A supply of seeds was secured by the experiment station from Porto Rico in 1904 and the plants have been grown on a field scale for two years. It gives promise of being a very useful plant.

The fruit of this plant consists of a fleshy calyx and a seed pod which are used in the making of jam, jelly, and a cooling drink. The flavor is tart and, if not obscured by the use of an excessive amount of sugar, resembles closely that of cranberries. In color and general appearance both the jam and the jelly are very attractive. The following directions for the manufacture of jam have been used in experiments conducted by Miss Alice R. Thompson, of this station. The data will also show the quantity of jam or of jelly which can be produced from a given number of pounds of fruit. These experiments were conducted with fruit that was rather overmature and the seed pod was too ripe to be used. When fruits are young the whole of the fruit may be used.

Roselle jam.—Wash 6 pounds of roselles, open and remove the seed pod. The weight of flesh will be about 3 pounds. Add 2 cups of water to the berries and cook about an hour until reduced to a soft pulp. Measure the cooked fruit and add 1¼ cups of sugar to each cup of fruit. Cook twenty minutes.

Six pounds of roselles will make 7 pounds of jam or 11 half-pint cupfuls.

Roselle jelly.—Wash and seed 4 pounds of roselles. The weight of the flesh will be about 2 pounds. Add 4 cups of hot water and boil to a pulp. Strain the whole through a cloth bag without pressing. Measure the juice and boil it continuously twenty minutes. Then add 1 cup of sugar for each cup of juice. The sugar should be heated in the oven before adding it to the juice, so that the boiling will not be interrupted. Cook until, on testing the consistency of the liquid by pouring from a spoon, the last drop adheres to the spoon. Remove from the fire and pour into the jars. Four pounds of roselles will make 2 pounds of jelly or 2 half-pint cupfuls.

Cultivation of roselle.—It is best to plant the seeds in boxes or seed beds about the last of February or the first of March in Honolulu and

transplant to the open field when the plants have attained a height of 6 or 8 inches. From the experience of the last two years at the station, there appears to be nothing gained by planting seed earlier than February. Seed planted before this date has produced plants which have borne prematurely and have not produced the main crop earlier than those from seed planted later. The plants should stand about 3 to 4 feet apart in the row and the rows from 4 to 6 feet apart. If the soil is good and moisture abundant, 4 by 6 feet will not be too great a distance.

The soil for the roselle need not, however, be the richest, but good soil will yield correspondingly good results. The harvest comes on about November and December in Honolulu. It is quite possible that in other parts of the islands other seasons for planting may be found preferable and the crop may mature earlier or later.

The after cultivation will consist only in keeping the soil well tilled and supplied with moisture.

The yields in the experiments conducted at the station would average from 6,000 to 7,000 pounds per acre with a very moderate use of water. The cost of picking these fruits would be from ½ to ⅝ of a cent a pound. At 4 cents per pound net to the grower, these fruits could be placed on the market at a price very much lower than cranberries. Allowing ¾ of a cent for the cost of gathering and ¼ of a cent for packing materials, there would remain 3 cents per pound as the value of the fruit on the plants. These at 6,000 pounds per acre would represent a value of $180 per acre for the crop in the field.

THE NATAL PINEAPPLE.

Specimen plants of the "Natal pineapple," S. P. I. No. 8634, were received and planted August 9, 1905. These plants have fruited during May and June. The aim of the U. S. Department of Agriculture in introducing this fruit has been to place upon the market a fruit of unusual quality in very small size so that they could be served one at each plate. The fruit is small, of very fine color, aroma, and exquisite flavor. No points of difference, however, could be distinguished between this and the Queen variety. They appear to be the same fruit under two different names. This fruit would not be well adapted to canning, but might be desirable for some of the fresh fruit markets where a small fruit is demanded. The Queen is not commercially planted in Hawaii at present, many plants having been destroyed. The Smooth Cayenne has given better results on the island of Oahu, where the largest pineapple plantations are located. This is no doubt due chiefly to its large size and heavy yields. The Red Spanish has found favor in Kona on the island of Hawaii.

GRAPES.

Quite a large number of varieties of grapevines were introduced during the last year, and were placed in charge of a vineyard company on the island of Maui. Some of these varieties are reported to have done unusually well and give promise of being a more profitable vine than those now common in the islands.

MANILA HEMP.

The Manila hemp plant was introduced into Hawaii many years ago, but so far as known to the writer has never been grown on a commercial scale. Seeds of this species were obtained by the station several years ago from which quite a number of plants were grown. These have made a more vigorous growth than any other species or variety of the genus Musa on the experiment station lands. There are many steep gulches in the islands where the Manila hemp might be grown and, judging from the progress which these trial specimens have made, should prove very profitable as a source of the much-prized rope fiber of commerce.

PLANTINGS ON THE HIGHER ELEVATIONS OF THE STATION LAND.

About 2 or 3 acres, at an elevation of approximately 1,000 feet, have been cleared during the year and planted to peaches, figs, oranges, lemons, pomelos, loquats, mulberries, grapes, and strawberries. A small planting of papaias and of citrus stocks for budding occupies part of this area. The coffee and most of the other plants at this elevation which have been set out in previous years are making satisfactory progress. The avocados on this land, which were planted many years before the station was established, are an interesting field for study in the causes of barrenness and also of lack of quality in the fruit. Some of the trees have refused to bear, while others have produced very indifferent fruits. These characters may be inherent in the trees or may be in part due to uncongenial environment. This elevation may approach the limit for the production of the best fruit. The effect of liberal fertilizing is being tried on some of these trees.

DECIDUOUS PLANTINGS.

The horticulturist superintended the planting of about 6 acres of deciduous orchards on lands belonging to the Parker ranch on the island of Hawaii, at elevations varying from 2,700 to 5,000 feet. These consisted of the following: 125 apples, 100 pears, 100 cherries, 100 apricots, 10 almonds, 10 walnuts, 100 plums, 100 peaches, 10 figs, 5 oranges, and 5 lemons.

A few apple trees, which were planted at about 4,000 feet altitude several years ago, have made a very fine growth and were well supplied with fruit buds at the time when the last plantings were made. This is mentioned here as of considerable interest, being perhaps the largest mixed planting of deciduous fruits that has been made in the islands.

DISTRIBUTION OF SEEDS AND PLANTS.

The distribution of seeds and plants has come to be a very considerable factor in our work. The station can in this way be of direct assistance to many. The aim has been to distribute such species and varieties as are not readily obtainable elsewhere. The miscellaneous distribution of ordinary vegetable and flower seeds has not been encouraged.

The request for varieties of bananas from the station collection has exceeded the supply in all varieties except the Jamaica or Bluefields. There have been requests from many parts of the Tropics for specimens of the Hawaiian bananas and to such a degree that it has been necessary to suspend further distribution during part of the year.

The number of visitors at the station who wish to look through the grounds and propagating houses has increased greatly during the year. Instruction in methods of cultivation has thus been given verbally and by demonstration, including such subjects as budding, grafting, pruning, etc. In some cases it has been necessary for the horticulturist to visit the grounds of the inquirer.

HORTICULTURAL EXHIBIT.

In December, 1906, the station cooperated with the Hawaiian Poultry Association in a public exhibition held in Honolulu. The horticulturist gave considerable time to the collection and arrangement of specimens for this exhibit. Though not a good season for an exhibit of horticultural products, by the cooperation of many interested parties a creditable collection of specimens was brought together. This fair had certainly considerable educational value, and arrangements have been made for another exhibit during the coming season.

The horticultural exhibit on the part of the station consisted chiefly in fruit packages, illustrative of methods of packing used in fruit-shipping experiments of the preceding season. The roselle was also shown in quantity and attracted much attention as a new fruit worthy of cultivation.

THE NEED OF ASSISTANCE.

The work of the propagating houses and the experimental plats and orchards has greatly increased, demanding constant and careful attention. With the other work that has been done it has been impossible to devote as much time to this as it requires. During the past year the horticulturist has been absent from the station on official duty about three months, a considerable portion of which was spent on the mainland of the United States.

The need of an assistant has been recognized for a long time, and only the lack of sufficient financial resources has prevented the securing of aid. It is expected that a man can be secured during the next few months. This should add greatly to the efficiency of the work.

REPORT OF THE ASSISTANT CHEMIST.

By Miss Alice R. Thompson.

During the past year a large number of miscellaneous analyses were made, among them 49 samples of Hawaiian honey, special attention being given to the honeydew honey; 13 samples of fertilizers were analyzed for the fertilizer experiments carried on with rice by Mr. F. G. Krauss; 10 samples of soils of different origin; several salt determinations of waters and soils, and about 40 samples of fodders and feeding stuffs. The analyses of the honey samples are reported in a bulletin of the station.[a] The other analyses, except the fertilizers, are given in the accompanying tables.

ANALYSES OF HAWAIIAN SOILS.

Ten samples of soils were received and analyzed and the analyses are as follows:

Analyses of samples of Hawaiian soils.

Number of sample.	Moisture.	Organic matter and combined water.	Nitrogen.	Phosphoric acid.	Potash.	Lime.	Magnesia.	Manganese oxid.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1	10.980	28.242	1.036	0.191	0.132	1.995	3.376	0.225
2	10.707	25.499	.840	.159	.145	1.880	3.687	.185
3	7.309	16.942	.313	.172	.361	.27	.608	.37
4	6.629	17.914	.238	.264	.515	.275	.535	.105
5	8.435	9.253	.232	.436	.324	1.470	1.575	.070
6	10.466	18.100	.477	.322	.126	1.135	1.838	.075
7	10.568	18.667	.435	.102	.331	.480	.835	.075
8	8.222	17.091	.336	.045	.339	.275	.559	.160
9	8.028	18.907	.273	.146	.283	.130	.711	.105
10	8.786	10.224	.153	.275	.659	.995	3.500	.20

Samples 1 and 2 were taken at Olaa, Hawaii. Both are brown sandy soils and acid in reaction with litmus paper, in spite of the amount of lime present, as shown by analysis. The potash content is low. Soil No. 1 has produced some sugar cane. Soil No. 2 is from coffee land.

Samples 3 and 4 were taken from pineapple land on Kauai. The pineapples growing on the soil were troubled with root disease. Both soils are brown loams and they react acid with litmus. Analysis shows a deficiency of lime in the soils.

[a] Hawaii Sta. Bul. 17.

Sample 5 is soil from the rice fields at the experiment station trial grounds. The soil is a gray loam, is not acid, and contains but a trace of chlorin.

Samples 6 and 7 were taken at Keanae, Maui. Sample 6 is a dark sandy soil, acid in reaction, and containing a trace of salt. Analysis shows a deficiency of potash.

Sample 7 is a brown sandy soil, also acid in reaction. Analysis shows a deficiency of lime.

Samples 8 and 9 are from Hanapepe, Kauai. Pineapples are raised on this soil. Both soils are brown loams and acid. The lime content is low in both. Phosphoric acid is low in No. 8.

Sample 10 was taken at Kaimuku. The soil is a red clay loam.

SALT DETERMINATION IN WATERS AND SOILS.

Mr. J. P. Colburn sent to the station for salt determination three samples of water from wells to be used in irrigating rice fields. Sample No. 1 contained 129.41 grains per gallon, No. 2 contained 74.53 grains, and No. 3 contained 113.83 grains.

To determine the amount of salt tolerated by rice Mr. F. G. Krauss, rice expert, brought two samples of water from rice fields for analysis. Sample No. 1, water in which rice grew well, showed a salt content of 1.69 grains to the gallon. Sample No. 2, from a rice field in which only rice of an inferior quality grows, contained 56.915 grains per gallon. The rice field from which the latter sample was obtained comes in contact with tide water.

From these results it would seem that rice fields irrigated with water containing 74.53 grains per gallon could produce rice of inferior quality. Mr. Colburn's sample No. 1 indicates a water of even higher salt content, which even rice of inferior quality would scarcely tolerate.

Another sample of irrigation water was submitted and on analysis was found to contain 9.316 grains of salt per gallon.

The salt content of four samples of soil was later determined. These samples were selected by Mr. F. G. Krauss from rice fields in which the salt content varied. The samples upon analysis were found to contain 0.00556, 0.00092, 0.00037, and 0.00002 gram of sodium chlorid per gram of sample. The first three samples were taken from Waikiki rice fields and the fourth sample was from the station's trial grounds near Waikiki. In the first soil rice does not grow, in the second it barely survives, while in the third soil it grows well.

COMPOSITION OF HAWAIIAN FEEDING STUFFS.

The analysis of fodders has continued to be part of the routine work to the laboratory. Forty samples have been analyzed, the methods used being those adopted by the Association of Official Agricultural Chemists. Reference may be made to Bulletin No. 13 of this station, which contains the analyses of a number of Hawaiian feeding stuffs, the present report being a continuation of the work as set forth there.

The composition of the fodders analyzed is as follows:

Composition of Hawaiian feeding stuffs.

Kind of feeding stuff.	Proximate constituents.						Ash constituents.		
	Water.	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	Ash.	Potash.	Lime.	Phosphoric acid.
NONSACCHARINE AND SACCHARINE FORAGE.									
Sorghum:	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*Per ct.*
Sample No. 1	75.11	1.71	1.76	13.56	5.45	2.41	0.31	0.12	0.09
Sample No. 2	78.92	1.38	.34	11.67	5.59	2.10	.27	.10	.09
Sample No. 3	62.79	2.53	.74	22.03	8.54	3.37	.....	.19	.25
Average	72.27	1.87	.91	15.75	6.52	2.62	.29	.13	.11
Sorghum silage	76.76	2.04	.73	12.62	5.68	2.17	.38	.08	.13
Corn cut for silo	76.45	1.64	.24	12.67	6.43	2.57	.33	.08	.12
Corn silage	81.63	2.06	.31	6.61	4.35	5.04	.48	.16	.09
Millet roots (*Sorghum halepense*), air dried	11.18	7.22	.39	27.56	40.82	12.83	2.60	.06	.19
GRASSES.									
Hilo grass (*Paspalum conjugatum*):[a]									
Sample No. 1	70.48	1.52	.40	16.43	9.44	1.73	.40	.19	.06
Sample No. 2	71.70	1.43	.54	15.18	9.39	1.76	.43	.15	.06
Sample No. 3	73.20	1.38	.86	14.02	9.05	1.49	.37	.18	.06
Average	71.79	1.44	.60	15.21	9.29	1.66	.40	.17	.06
Rhodes grass (*Chloris gayana*):[b]									
Sample No. 1	64.78	2.81	.52	16.08	12.52	3.26	.50	.26	.16
Sample No. 2 (air dried)	10.87	9.00	1.53	38.05	27.36	13.19	1.31	.71	.95
Pili grass (*Heteropogon contortus*)[c]	66.93	2.05	.44	15.43	11.79	3.36	.44	.08	.13
Redtop (*Tricholæna rosea*), air dried	8.84	3.38	1.21	45.14	35.48	5.95	.59	.33	.28
Paspalum dilatatum[d]	72.95	1.96	.72	13.38	8.86	2.13	.52	.20	.12
Para grass (*Panicum molle*):[e]									
Sample No. 1	72.18	3.46	1.33	11.04	7.65	4.34	.....	.16	.24
Sample No. 2	72.10	1.43	.29	13.31	11.19	1.68	.08	.09	.12
Side oats grama (*Bouteloua curtipendula*)[f]	39.47	6.43	1.05	27.68	18.12	7.25	.71	.21	.27
English and Italian rye grass (*Lolium perenne* and *L. italicum*)[g]	27.44	6.49	1.43	36.68	20.94	7.02	1.86	.44	.41
Wheat hay (containing a little oats)[h]	11.91	7.96	.94	38.27	30.09	10.83	3.31	.20	1.03
Rice straw[i]	10.89	4.81	2.67	36.91	24.84	19.88	.....	.39	.41

[a] From Parker ranch, No. 1 below Baker's, No. 2 from Waihaka, and No. 3 at Baker's.
[b] No. 1 from Molokai ranch, 800 feet; No. 2 from Parker ranch.
[c] From Molokai ranch, 700 feet.
[d] From Molokai ranch.
[e] No. 1 from Waikiki, Oahu; No. 2 from Olaa.
[f] Grown at the experiment station, Oahu.
[g] From Parker ranch.
[h] From Waimea.
[i] Grown at Waikiki, Oahu.

Composition of Hawaiian feeding stuffs—Continued.

Kind of feeding stuff.	Proximate constituents.						Ash constituents.		
	Water.	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	Ash.	Potash.	Lime.	Phosphoric acid.
LEGUMINOUS FORAGE CROPS.									
Alfalfa:[a]	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*Per ct.*
Sample No. 1	76.61	6.78	0.77	8.73	4.24	2.87	0.98	0.39	0.21
Sample No. 2	73.83	5.25	.76	11.21	5.56	3.39	1.00	.35	.23
Sample No. 3	72.18	8.00	.72	9.44	6.27	3.39	.....	.50	.22
Average	74.20	6.67	.75	9.79	5.35	3.21	.99	.41	.22
Cowpea (*Vigna sandwichensis*)[b]	82.35	3.06	.58	7.24	4.22	2.55	.62	.34	.14
ROOTS USED AS FORAGE.									
Cassava refuse from crude extract of starch	15.46	1.21	.10	76.93	5.45	.85	.314	.17	.04
Cassava waste (first washing for starch manufacture)	16.30	1.31	.22	79.82	1.08	1.27	.08	.10	.08
Taro waste	70.73	.36	.24	27.25	.89	4.36	.13	.05	.07
Tacca pinnatifida	66.89	1.93	.12	29.64	.58	.84	.39	.06	.07
Ti root	46.78	3.76	.16	42.28	5.40	1.62	.27	.56	.09
Beet, Yellow Tankard	94.12	1.00	.04	2.62	.97	1.25	.40	.02	.05
Beet, Long Red	93.25	1.13	.06	1.80	2.59	1.17	.32	.02	.05
CONCENTRATED FEEDS.									
Algeroba, or kiawe bean (*Prosopis juliflora*):[c]									
Sample No. 1	13.62	8.13	.67	52.38	21.87	3.33	1.35	.19	.28
Sample No. 2	16.37	8.50	.44	53.77	17.47	3.44	1.22	.23	.36
Sample No. 3	15.17	9.73	.45	47.12	23.71	3.82	1.38	.43	.33
Algeroba meal	9.29	10.25	1.16	47.98	27.85	3.52	1.22	.24	.39
MISCELLANEOUS FORAGE CROPS.									
Spanish needles (*Bidens pilosa*)[d]	82.06	3.45	.33	6.48	5.03	2.65	.94	.26	.14
Pakana (*Melilotus officinalis*)[e]	61.28	5.96	.67	17.59	11.90	2.60	.94	.50	.28
Rape[d]	86.10	2.24	.59	6.60	1.76	2.71	.95	.32	.16
Annual ilima (*Sida* sp.)[d]	77.58	3.93	.39	8.88	5.69	3.53	.81	.80	.32

[a] No. 1 and 2 from experiment station, Oahu; No. 3 grown at Waikiki, Oahu.
[b] From Kamehameha Schools, Oahu.
[c] Sample No. 1 was passed through a sieve having $\frac{3}{16}$-inch meshes, No. 2 through a sieve having $\frac{1}{8}$-inch meshes, and No. 3 was chopped coarse.
[d] From Molokai ranch.
[e] From Parker ranch.

Composition of Hawaiian feeding stuffs.

[Dry-matter basis.]

Kind of feeding stuff.	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	Ash constituents.		
					Potash.	Lime.	Phosphoric acid.
NONSACCHARINE AND SACCHARINE FORAGE.							
Sorghum:	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Sample No. 1	6.89	7.08	54.45	21.90	1.23	0.48	0.35
Sample No. 2	6.53	1.60	55.39	26.52	1.30	.48	.43
Sample No. 3	6.81	2.00	59.18	22.95	.....	.52	.67
Average	6.74	3.56	56.34	23.79	1.26	.49	.48
Sorghum silage	8.78	3.14	54.29	24.45	1.62	.36	.55
Corn cut for silo	6.97	1.01	53.78	27.31	1.40	.34	.05
Corn silage	11.19	1.70	35.96	23.69	2.59	.88	.49
Millet roots (*Sorghum halepense*)	8.13	.44	31.02	45.96	2.93	.07	.21

Composition of Hawaiian feeding stuffs—Continued.

[Dry-matter basis.]

Kind of feeding stuff.	Protein.	Fat.	Nitrogen free extract.	Crude fiber.	Ash constituents.		
					Potash.	Lime.	Phosphoric acid.
GRASSES.							
Hilo grass (*Paspalum conjugatum*):	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Sample No. 1	5.14	1.35	55.66	31.99	1.35	0.65	0.22
Sample No. 2	5.04	1.92	53.62	33.18	1.52	.53	.26
Sample No. 3	5.14	3.22	52.31	33.78	1.37	.69	.22
Average	5.10	2.16	53.86	32.98	1.41	.62	.23
Rhodes grass (*Chloris gayana*):							
Sample No. 1	8.01	1.47	45.65	35.62	1.41	.74	.45
Sample No. 2	10.04	1.72	42.78	30.69	1.47	.79	1.06
Average	9.02	1.59	44.21	33.15	1.44	.76	.75
Pili grass (*Heteropogon contortus*)	6.2	1.31	46.70	35.64	1.34	.24	.39
Para grass (*Panicum molle*):							
Sample No. 1	12.44	4.78	39.67	27.51	.....	.56	.87
Sample No. 2	5.13	1.03	47.70	40.11	.29	.34	.42
Redtop (*Tricholæna rosea*)	3.71	1.32	49.53	38.92	.64	.36	.30
Paspalum dilatatum	7.25	2.67	55.97	32.77	1.92	.74	.44
Side oats grama (*Bouteloua curtipendula*)	10.63	1.73	45.72	29.94	1.18	.34	.44
English and Italian rye grass (*Lolium perenne* and *L. italicum*)	8.94	1.97	51 15	28.86	2.57	.61	.57
Wheat hay (containing some oats)	9.04	1.07	43.44	34.16	3.76	.23	1.16
Rice straw (upper half as gathered)	5.38	2.99	41.44	27.88	.....	.44	.46
LEGUMINOUS FORAGE CROPS.							
Alfalfa:							
Sample No. 1	29.00	3.70	36.91	18.12	4.21	1.69	.88
Sample No. 2	20.06	2.91	42.81	21.26	3.83	1.33	.89
Sample No. 3	28.75	2.58	33.94	22.55	.....	1.81	.80
Average	25.93	3.06	37.88	20.64	4.02	1.61	.85
Cowpea (*Vigna sandwichensis*)	17.31	3.29	41.03	23.93	3.52	1.94	.78
ROOTS USED AS FORAGE.							
Cassava refuse from crude extract of starch	1.44	.12	90.99	6.45	.37	.19	.05
Cassava waste (first washing for starch manufacture)	1.57	.26	95.37	1.29	.09	.12	.10
Taro waste	1.24	.83	93.41	3.03	.46	.16	.22
Tacca pinnatifida	5.82	.35	89.55	1.74	1.19	.18	.22
Ti root	7.06	.30	79.45	10.14	.50	1.05	.16
Beet, Yellow Tankard	17.06	.74	44.41	16.51	6.78	.28	.90
Beet, Long Red	16.87	.85	26.62	38.36	4.80	.24	.79
CONCENTRATED FEEDS.							
Algeroba, or kiawe bean (*Prosopis juliflora*):							
Sample No. 1	9.38	.77	60.69	25.31	1.56	.22	.33
Sample No. 2	10.14	.53	64.33	20.88	1.45	.28	.43
Sample No. 3	11.44	.53	55.56	27.95	1.62	.51	.39
Algeroba meal	11.26	1.27	52.90	30.70	1.34	.26	.43
MISCELLANEOUS FORAGE CROPS.							
Spanish needles (*Bidens pilosa*)	19.28	1.82	35.99	28.11	5.27	1.46	.81
Pakana (*Melilotus officinalis*)	15.39	1.74	45.43	30.73	2.44	1.30	.72
Rape	16.10	4.24	47.46	12.69	6.86	2.30	1.51
Annual ilima (*Sida* sp.)	17.55	1.76	39.55	25.37	3.62	3.60	1.46

Nitrogenous constituents of Hawaiian feeding stuffs.

[Fresh material.]

Kind of feeding stuff.	Total nitrogen.	Proteid nitrogen.	Amid. nitrogen.	Crude protein (total N×6.25).	True protein (protein N×6.25).	Amids calculated as asparagin.
NONSACCHARINE AND SACCHARINE FORAGE.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Sorghum: Sample No. 1	0.274	0.244	0.030	1.71	1.53	0.14
Corn	.260	.181	.079	1.63	1.13	.37
GRASSES.						
Rhodes grass (*Chloris gayana*): Sample No. 1	.451	.278	.173	2.82	1.74	.81
Water grass (*Paspalum dilatatum*)	.314	.054	.260	1.96	.34	1.22
Pili grass (*Heteropogon contortus*)	.328	.245	.083	2.05	1.53	.29
LEGUMINOUS FORAGE CROPS.						
Cowpea (*Vigna sandwichensis*)	.489	.369	.120	3.06	2.31	.56
ROOTS USED AS FORAGE.						
Beet, Yellow Tankard	.161	.072	.089	1.01	.45	.42
Beet, Long Red	.182	.095	.087	1.14	.59	.41
CONCENTRATED FEEDS.						
Algeroba or kiawe bean (*Prosopis juliflora*):						
Sample No. 1	1.295	.781	.514	8.09	4.88	2.42
Sample No. 2	1.358	1.141	.217	8.49	7.13	1.02
MISCELLANEOUS FORAGE CROPS.						
Spanish needles (*Bidens pilosa*)	.552	.095	.457	3.45	5.94	2.15
Rape	.358	.289	.069	2.24	1.81	.32
Annual ilima (*Sida* sp.)	.629	.428	.201	3.93	2.68	.94

RICE INVESTIGATIONS—REPORT OF FIRST YEAR'S EXPERIMENTS.

By F. G. Krauss.

INTRODUCTION.

Rice, while second to sugar as an agricultural product and far below it in magnitude and value, is still the most extensively consumed in Hawaii of any product of the land. If every other crop should fail and supplies from the mainland be cut off, the subsistence of its inhabitants would be assured by this one staple crop.

The growing of rice occupies 10,000 or more acres, and as practiced in Hawaii it is an intensive rather than an extensive culture, 100 acres constituting a large plantation. The rentals of rice lands are high, ranging from $10 to $50 per acre per annum with water privileges. This necessitates careful and continuous culture to produce maximum crops, although the annual acre yields in Hawaii compare favorably with the best in the world. Two crops a year are usually grown on the same land, thus occupying the ground continuously, especially when slow-maturing varieties are grown. The usual practice is to propagate the seedlings in seed beds, from which the entire crop is transplanted by hand.

Tillage methods, while antiquated, are thorough, as is also the practice of irrigation and drainage. To a limited extent the application of fertilizers is followed. The sickle is used in reaping, thrashing for the most part is done by the treading of horses, and the grain is winnowed by hand.

The average annual yield (two crops) on good lands in favorable localities is 6,000 pounds of paddy per acre, while 8,000 pounds or more is not uncommon. At present prices,[a] which are exceptionally good, an acre will produce a crop valued at from $100 to $200. The estimated annual value of the Hawaiian rice crop in a favorable year is approximately $2,500,000.

In this report little more than a record of a first series of experiments is attempted. The data presented, however, were obtained under favorable conditions and should prove reliable on this account.

[a] The price of paddy (unhulled rice) is about half of that of the milled marketable table rice, and during the spring of 1907 ranged from $2.20 to $2.70 per 100 pounds.

The writer desires to acknowledge the valuable assistance and cooperation of Messrs. Ching Shai, Wong Leong, and Ching K. Ai, prominent Hawaiian rice growers; Dr. N. A. Cobb, in the work on the diseases affecting Hawaiian rices and upon the sedges entering into these experiments; Mr. D. L. Van Dine, entomologist of the station, in determining insect pests affecting rice; and Miss Alice Thompson, assistant chemist, in preparing the chemical data affecting these experiments and in making numerous calculations. To Director Jared G. Smith's valuable suggestions and constant encouragement the main credit of much of this work is due.

PLANS, OBJECTS, AND METHODS OF THE EXPERIMENTS.

The past year has been devoted to a study of the fertilizer requirements of the rice plant and of rice soils, and to the development of superior varieties and strains of rice through the improvement of some of the best of the old varieties and by selection from the best foreign varieties. In connection with the experiments an exceptional opportunity was offered for determining a number of other factors in the production of rice. Among these are the influence of the age of seedlings at the time of transplanting; tillering of the rice plant as affected by the number of seedlings set in a clump at transplanting; relative yields from broadcasted, drilled, and transplanted rice; and the duty and influence of irrigation water.

In pursuing these investigations field trials were made of rice machinery. These took up comparatively little time, but sufficient was done to interest implement manufacturers, who will probably make more exhaustive tests than are possible by the station.

The station was fortunate in securing a conveniently located tract of land for experimental purposes. This land had been under rice culture for a number of years, excepting a small portion, which was planted to bananas at the time it was turned over to the station, in August, 1906. That portion which had been devoted to rice growing had received no fertilizer for a number of years, yet it had invariably yielded crops approximating 3,000 pounds of paddy per acre per harvest. However, owing to the porous nature of the soil, which necessitated an excess of irrigation, other crops were being gradually substituted for rice.

A chemical analysis of the soil was made at the time the station took possession of the land in 1906, and its principal constituents are shown in the following table:

Partial chemical analysis of the soil of the rice trial grounds.

	Per cent.
Moisture	8.435
Organic matter combined with water	9.253
Lime (CaO)	1.470
Magnesia (MgO)	1.575
Phosphoric acid (P_2O_5)	.436
Potash (K_2O)	.324
Nitrogen total	.232

This analysis shows the soil to be of fair fertility, although low in organic matter. Fully 25 per cent of this soil is coarse gravel and stone, an equal amount is fine gravel and coarse sand, and the remainder fine sand and silt with sufficient clay to permit of puddling the land to hold water enough for the crop.

An artesian well supplied ample pure water for irrigation purposes and avoided contamination in fertilizer experiments.

NOTES ON VARIETY TESTS AND IMPROVEMENT EXPERIMENTS.

In taking up the rice work the station secured as many varieties as possible, and early in 1906 succeeded in obtaining through the Office of Experiment Stations and the Bureau of Plant Industry of the U. S. Department of Agriculture about 150 more or less distinct varieties of rice. The descriptions and other data accompanying many of these varieties were meager but were carefully recorded, in order that the original descriptions could be compared with specimens grown from the different samples. A 10-gram sample of each variety was reserved for future reference, and these have already proved invaluable in the study of varieties in the two succeeding generations.

So far as the physical characteristics of the unhulled seed are concerned, comparisons that have thus far been made show but slight variation from the original specimens, except in color, the hulls invariably changing to a darker color with age, probably under the influence of light. It is possible that changes in environment may alter the chemical composition of the grain, and investigations in this direction are now under way.

Germination tests were made of all samples in the laboratory. One hundred and thirty-one varieties germinated, although some showed very weak vitality, due probably to the age of the seed, immaturity at harvest, or insect injury.[a] In several cases the bulk of the seed packet consisted of empty sterile glumes. The few seeds germinating from one of these lots produced perfect plants with a full crop of well-matured seed, while in another instance every flowering glume of the entire plant proved sterile. This would probably indicate a

[a] Several lots of seed, among them S. P. I. Inv. No. 12547, were found to be badly infested with the weevil (*Rhizopertha pusilla*).

tendency toward sterility on the part of that particular variety, since the weather conditions were perfect at flowering time and the adjacent varieties fruited abundantly.

Some stress is laid upon this point, as it frequently happens that in large fields numerous sterile or partially sterile plants are to be found which collectively would considerably reduce the yield. In the improvement of varieties any tendency toward a reduced yield is to be avoided. Whether the tendency to sterility can be transmitted remains to be determined.

In the improvement of varieties by selection as well as in testing varieties in cultural trials, it is of the utmost importance to know definitely their methods of pollination. In the case of the rice plant it has been generally supposed that cross-fertilization is the rule and self-fertilization the exception. Apparently the whole flowering process is favorable to cross-fertilization. The successive stages in the flowering are readily traced from the time in which the glumes open until they close together, enveloping the recently exposed stigma, and now containing the fertilized ovule which is to become the matured seed. The whole process of fertilization in rice is similar to that in wheat described by Hays,[a] except that the rice floret bears six anthers and opens generally between 9 and 10 o'clock in the morning and frequently does not close until noon. The flowering period of an individual floret is usually completed within an hour.

Based upon careful observation and experiment, the writer believes that self-fertilization is the rule in rice as it apparently is in wheat. Since these rice experiments were inaugurated more than 100 varieties have been grown in close proximity for from two to four generations without a single cross-bred plant having been found. To test the belief in self-fertilization numerous individual plants of several varieties were protected from foreign pollen by double fine gauze bags before the flowering stage, and all fertilized perfectly except those experimented with during periods of heavy rain.

In the original more than 100 varieties of rice received at the station from many sources there appeared considerable mixtures, which were at first believed to be due to deterioration or possibly to results of accidental crossing. To determine this point a variety grown experimentally at the Georgetown Botanical Gardens from imported Ceylon stock was selected as being the most impure of any. From this six or seven distinct types were separated and grown separately. All but one reproduced themselves closely as to type, so far as the physical appearance of the paddy was concerned. The second generation is now maturing, and, so far as harvested, each of the selections seems to maintain its original physical type.

[a] U. S. Dept. Agr., Div. Veg. Physiol. and Pathol. Bul. 29.

FIG. 1.—GENERAL VIEW OF RICE PLATS.

FIG. 2.—UPLAND RICE GROWN UNDER MINIMUM AMOUNT OF WATER.

A number of theories have been advanced to explain the cross-fertilization of cereals, but the author believes that the stigma does not become receptive until at the very moment the anthers shed their pollen. The pollen is then immediately received on the stigma and fecundation takes place. This seems to be borne out by the great rapidity with which the ovules develop. If this theory is true, the subsequent contact of foreign pollen is without influence. If, however, for some reason the stigma fails to receive pollen from the anthers in the same floret, then a deposit of foreign pollen may fertilize, even after a considerable interval of time. So far as the experiments have been carried on, however, there seems to have been no indication of crossing in the field.

METHODS OF CULTIVATION.

In the trial grounds near Honolulu an acre was divided into plats (Pl. V, fig. 1), and half of the tract was diked for permanent flooding and the remainder left for dry-land culture (Pl. V, fig. 2). It was planned to test each variety in both cultures to determine their drought-resisting and water-tolerance properties. After thoroughly tilling the land in a dry state with disk implements to a depth of 6 inches the first water was turned on August 20, previous to sowing the seed. In Hawaiian rice culture much of the tillage is done while the field is submerged. This is done partly to puddle the ground, thus economizing the irrigation water. The soil of these experimental plats being of a porous nature, as has already been mentioned, prevented any accumulation of surface water, and this necessitated the thorough puddling of the land, which was done with horses and a spike-tooth harrow. After this had been accomplished the 2-inch stream available supplied all the irrigation water needed.

After irrigating the tract the water was allowed to recede, and on account of the gravelly nature of the soil the drilling of the seed was commenced within forty-eight hours. To give all varieties an even start the entire list was sown August 25, flooded and immediately drained again, and so left until all the varieties had made several inches' growth.

Marked differences were noted in the germination of the varieties, the differences being due, it is believed, to the age of the seed, their moisture content, and the imperviousness of the hulls. The first varieties appeared above ground in fifty-eight hours and the last in one hundred and twenty-five hours, but no subsequent sowings from home-grown stocks have shown anything like as wide a range in germination. When the plants had attained a height of about 6 inches, they were thinned so as to stand about 6 inches apart. Equal numbers of the strongest, weakest, and intermediate plants were permitted to remain for the sake of obtaining as great diversity as pos-

sible. After the thinning was completed the land was permanently flooded.

Field notes were made throughout the season and comparisons made between the different varieties and several standard Hawaiian varieties under identical conditions. Records were kept of the amount of seed sown, tillering, date of flowering, date of maturity, germination, vigor, date of harvest, height and spread of plant, inclination to lodge, shattering of seed, freedom from disease, total yield and variation in yield of individual plants, quality, etc.

BREEDING EXPERIMENTS.

As each variety matured it was carefully inspected and all sports and rogues staked and recorded. The variety was then examined a second time and the best 20 plants pulled up by their roots. These were taken to the laboratory, and the fruit-bearing culms carefully compared until all but five plants were eliminated. The seeds of these were removed and weighed to determine the relative yields. Other things being equal, the two most prolific were reserved as seed for mother plants from which to develop a pedigreed stock. Wherever possible 100 plants of the unselected stock, including the 18 rejected plants from the first selection, were carefully thrashed, weighed, and the approximate acre yields calculated. In this calculation 100 plants were taken as representing a factor in estimating acre yields. In Hawaiian rice culture approximately 50,000 clumps, consisting of 4 or 6 plants each, are set per acre.

It should be stated that in Hawaiian culture all rice is transplanted, while in most of the experiments here described the seed was drilled directly into permanent rows, so that the yields as recorded from the comparative variety tests are only approximations of what they might be under the usual cultural methods.

Of the one hundred and more varieties under test, 11 have thus far been selected as being suitable for Hawaiian conditions. A number of these are upland rices, which produce a fair yield with a minimum supply of moisture. They are all hardy, having been brought from northern China, are early maturing, and produce an excellent hay for horses and cattle. Though all are of the bearded type, no ill effects have been observed to result from their feeding. There is every reason to believe that the culture of upland or dry-land rice will become an important factor in Hawaii's agriculture.

Among the varieties were some promising wet-land rices of the short, thick-kernel type characteristic of Japan rice, the demand for which is yearly growing, on account of the large population of Japanese in Hawaii. One of these varieties was introduced into Hawaii in 1903 or 1904 by Mr. Wong Leong, an extensive rice grower at Kailua, Oahu. Mr. Wong Leong imported four varieties of rice

from Yokohama, Japan, only one of which proved suitable for Hawaiian conditions. Of this he now grows 50 to 80 acres annually and is constantly increasing the area. Comparatively little of this variety is grown elsewhere in Hawaii, but its culture is sure to extend as the demand for it increases.[a]

A pound sample of this variety was secured early in 1906 and sown in drills, the thinned-out plants being transplanted later. Much irregularity was noted as the plants matured. A small percentage showed a short-bearded form. Some tillered freely, while others produced only two or three fruiting culms. However, the seed set well, and its early maturity, compared with the slow-maturing Hawaiian varieties of the Gold Seed type, made a favorable impression from the first.

It was noticed in testing this variety that the transplanted seedlings tillered more freely and developed better panicles than the direct-sown seed; and, furthermore, that the earlier transplanted seedlings yielded almost twice as much seed as older seedlings transplanted later (see p. 88). This gives a valuable clue to a general complaint that the Japanese rices are small yielders when compared with the standard Hawaiian sorts. Careful selections were made of the best individual plants, and these form the basis of a choice pedigree strain which is about to be distributed by the station. This variety has been given a station inventory number, and it is frequently referred to in this report as No. 153.

A second variety, No. 144 (S. P. I. Inv. No. 12765), was received through the Office of Experiment Stations of the U. S. Department of Agriculture as coming from Japan and was labeled Ko-Zo.[b] The few seeds available were sown in August, 1906, but only a single plant was brought to maturity. The seed from this was preserved and carefully propagated. This variety tillers much more freely than No. 153, and the plants yield twice, and in some cases three times, as much paddy, although the grain is somewhat smaller in size. The quality of this rice is considered excellent, and the stock of it will be multiplied as rapidly as possible.

A variety known as No. 65 (S. P. I. Inv. 17144) is an Egyptian variety, extensively grown in Louisiana where, according to Dr. S. A. Knapp, it is locally known as "Bull Rice."[c] No variety in all the

[a] The Japanese residents in Hawaii prefer the rice imported from their own country, paying $1 more per 100 pounds for it.

[b] Possibly intended as Kiushu, a district in Japan where some of the best types of Japan rice are grown.

[c] Accompanying this variety were the following notes: "The Egyptian rice is locally known in Louisiana as 'Bull Rice' and has been grown there for many years. It has a berry of the Japanese type—that is, thick and short kernel, somewhat larger than the Kiushu rice, dark colored and much softer when it first ripens, so that it answers excellently for the purpose of stock feed.

trials has made as good a showing from the very beginning and maintained its lead so well as this. Its general uniformity, good yielding qualities under wet and dry cultural methods, erect, vigorous growth, apparently small waste in milling, and its adaptability for all-season cropping commend it strongly as a general-purpose variety. Its culinary qualities are yet to be determined.

A comparative study was made between plats of standard Hawaiian Gold Seed, Japan Seed rice, and the Egyptian variety just mentioned. These three varieties were grown under like conditions and represent results obtainable under the best methods of culture.

Comparison of standard Hawaiian Gold Seed, Japan Seed, and Egyptian varieties of rice.

Name of variety.	Station inventory number.	Date of sowing, 1907.	Date of maturity and harvest, 1907.	Growing period.	Height of plants.	Weight of paddy.[a]	Weight of straw.[a]	Estimated[b] acre yields, paddy.
				Days.	*Inches.*	*Grams.*	*Grams.*	*Pounds.*
Standard Hawaiian Gold Seed	148	Feb. 18	July 20	152	42	32	68	3,730
Hawaiian-grown Japan Seed	153	---do----	June 8	110	36	20	54	3,412
Hawaiian-grown Egyptian	65	---do----	July 20	152	48	43	114	4,129

[a] One clump consisted of three plants set 12 by 12 inches apart, except No. 153, which stood 9 by 9 inches apart.

[b] Based on 43,560 clumps to an acre for varieties Nos. 148 and 65, and 77,440 clumps to an acre for No. 153.

The comparison in this case is believed to be a fair approximation of these varieties. The estimates are based on test cuttings of 100 square feet, the range of error for which has been found to be within 150 pounds of the yield per acre.

Variety No. 152, which was received by the station from Mr. W. S. Lyon, horticulturist in the Bureau of Agriculture, Philippine Islands, under the name Ay-Yujip, from the Igorrote country, where it is classed as the very best rice grown, promises to become a valuable variety, especially for windy locations. In an extensive trial conducted with it during the fall and winter of 1906–7 the severe storms failed to lodge a single plant, and the grain set perfectly, yielding a large crop. The panicles are long and drooping, averaging 10 to 12 inches in length, and are well furnished with seed, though not so compactly as in variety No. 65. The grain is of a characteristic Japanese type, but owing to the short bearded or awned form of the paddy, it would probably not mill so economically as the beard-

It also has more protein than the ordinary rice. The characteristics of its growth are that it requires very little water, has a strong stalk, abundant leaf, is a heavy producer, and will generally make a crop even though the other rices fail. For these reasons it is grown as a stock feed. The seed of the particular rice sent in was obtained about five years ago [through a seed dealer of New Orleans]. It was the only seed which I could purchase which was free from red rice."—KNAPP.

less varieties. A considerable variation prevails in the extent of this awned form, and it is hoped that by selection it will be possible to establish an entirely beardless type. Considerable improvement is already noted in this direction.

Variety No. 42 (S. P. I. Inv. 12867) proved another promising variety, bearing very compact panicles of upright growth, which permits of close planting as an offset to its rather light tillering. This variety was sent to the station under the name Thosar Bhadai ghaiya, from Bengal Province, India.

In the search for a better variety than the Hawaiian Gold Seed, which is the variety grown most extensively in Hawaii, variety No. 39 (S. P. I. Inv. 12852) proved superior in many respects to our best Hawaiian varieties, which it closely resembles in general appearance. The selection made by the station has unusually compact panicles, the spikelets being attached to the peduncles at close intervals, set on short pedicels, which cause the spikelets to lie close together, often overlapping for two-thirds their length. In the Hawaiian strains of Gold Seed the panicles are rather loose and straggling, due to the longer internodes, so that a comparison between the panicles of the two strains shows 10 to 20 per cent more seed in favor of the new variety, due to this cause alone, since the panicles are of about equal size.

This close setting of the seed to produce compact panicles is an important character to be considered in developing the yielding power of rice through selection. It was so noticeable in the early experiments that its application has been practiced almost from the beginning. Attention has been called to this character by Dr. T. Nakamura, of Tokyo, and it has also been pointed out by Mr. Wong Leong, who called attention to its importance.

SUMMARY.

In the improvement of varieties of rice, it is found important to collect and compare as many varieties as possible. Superior varieties may already exist, and by their cultivation time and expense of creating new sorts would be saved. In work of this character selection should never cease, even among the best varieties.

In testing varieties by cultural trials, a single season's test is not sufficient for comparison. In rice, especially where two crops are grown annually, it is of importance to grow all varieties, testing them as spring and fall crops. The experiments have demonstrated that some varieties which yield well from July planting fail if sown in the early spring, or continue to vegetate until late fall, when they flower and fruit at about the same time as summer plantings. As an example of this No. 19 (S. P. I. Inv. 12508), sown August 25, 1906, yielded a splendid crop when harvested December 17, 1906.

On March 7, 1907, a large plat was sown to the same variety, and while the plants had reached the height of 5 to 6 feet on October 20 only an occasional plant was coming into flower. This indicates periods for maturity of 118 days for fall planting and 200 days for spring-planted crops.

All things considered, the all-season varieties are best for Hawaiian conditions, although exceptional qualities in fall varieties may sometimes be used to advantage in a cultural scheme. It may be laid down as a principle that spring varieties also produce fall crops, while fall varieties are not at all suited to spring culture. Fall varieties are usually slow maturing and heavy yielders; they tiller well, and have thick, stiff stems, being resistant to the effect of storms.

The commercial value of the several varieties which the station is about to introduce to the rice growers of Hawaii remains to be proved, and this can be done only in their hands under the varying and less ideal conditions of plantation management.

FERTILIZER AND CULTURE EXPERIMENTS.

INTRODUCTION.

The Hawaiian rice lands have long been noted for their fertility. Under the intensive cultural methods practiced by the Chinese they have yielded crops of extraordinary quantity and fine quality, and in consequence the industry has flourished. However, decreasing yields and deterioration in the quality of the grain are beginning to cause a general awakening. The causes of the smaller and poorer yields are the continuous cropping of lands with this one staple and the lack of a rational system of fertilization to compensate for the heavy drain imposed by the harvesting of two crops annually.

Ordinarily a rotation of crops would suggest itself as a feasible remedy, but the fact that rice is grown on submerged lands restricts its culture to very narrow limits. As a means for the restoration of worn-out rice lands resting the land has been advocated, but the high rentals prevailing practically prohibit the application of this remedy. Some advance has been made in this direction in that paddy fields are being more thoroughly drained at harvest, and the field is permitted to remain in stubble for as long a period as practicable. The fields are then plowed in a half-dry state and left exposed to the air and sun. After varying periods the land is flooded and the resulting mud mass very thoroughly mixed with the Chinese harrow (Pl. VI, fig. 1). This implement is a single-rowed, twelve-toothed contrivance of steel, resembling an immense comb, to which a water buffalo is attached where the land is very soft or a horse where there is good bottom.

FIG. 1.—CHINESE HARROW.

FIG. 2.—TRANSPLANTING RICE SEEDLINGS.

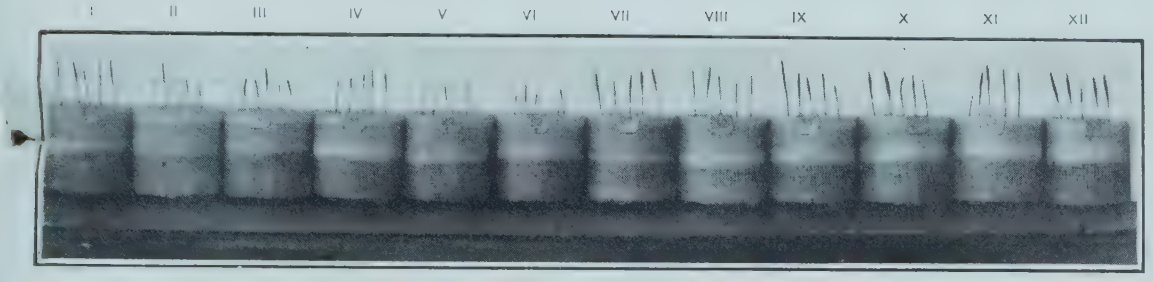


FIG. 1.—STAGE WHEN FIRST WEIGHED, AUGUST 15, 1906.

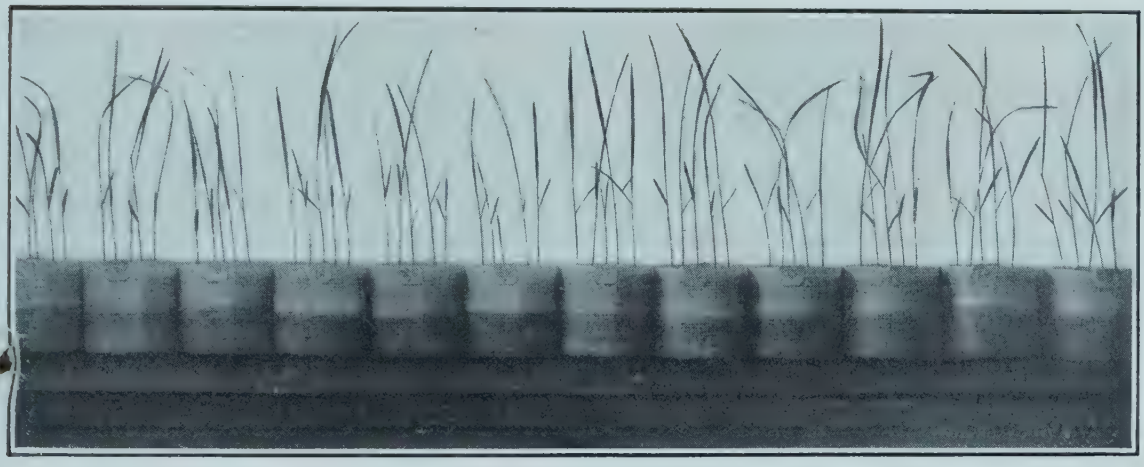


FIG. 2.—INTERMEDIATE STAGE, AUGUST 24, 1906.

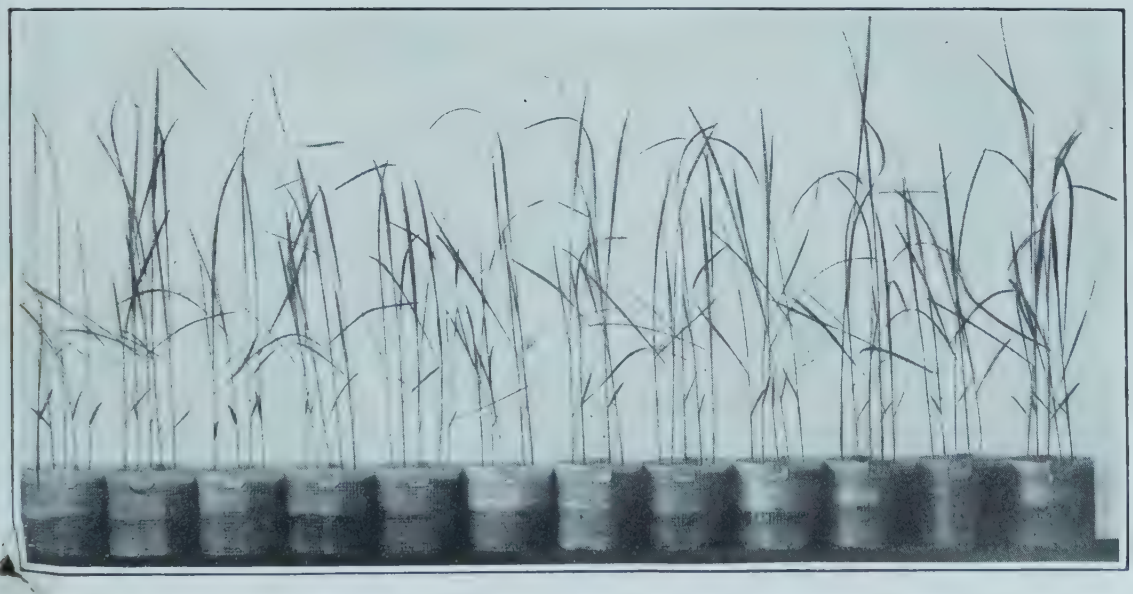


FIG. 3.—CONDITION AT FINAL WEIGHING, SEPTEMBER 24, 1906.

POT EXPERIMENTS WITH RICE, SHOWING EFFECT OF FERTILIZERS.

After this preparation the soil is in condition to receive the crop, and it should be borne in mind that all rice in Hawaiian culture is transplanted (Pl. VI, fig. 2). While such tillage prepares a suitable seed bed, the more important object of cultivation while the field is flooded is to puddle the soil so as to make it more retentive of water. The value of this treatment will be better appreciated when it is known that puddled soils retain their surface flooding from ten to fifty times better than unpuddled fields.

FERTILIZER EXPERIMENTS.

The possibility of economically increasing the yield of the rice crop by the application of commercial fertilizers has doubtless been apparent to many. One would think that in Hawaii, with its splendid object lesson of the results of fertilization of the cane crop, the analogy would readily have suggested itself with other crops. Beyond the application of natural manures, such as have been used for centuries in oriental countries, comparatively little seems to be known of modern methods in plant feeding in relation to the rice crop.

With a view to discovering if possible some of the fertilizer requirements of rice, a series of experiments was planned to determine the influence of chemical fertilizers and natural manures upon the growth and composition of the rice plant under Hawaiian conditions. Two series of soil tests were made by laboratory pot-culture methods, a duplicate series of field plat experiments, and two series of experiments on a field scale. The period covered by these experiments was about fifteen months, beginning July 1, 1906.

The first experiment undertaken was the determination of the manurial requirements of the soil of the rice trial grounds (Pl. VII). For this purpose the paraffined wire-pot method devised by the Bureau of Soils of the U. S. Department of Agriculture was used.[a] This method possesses several advantages over the more cumbersome pots ordinarily used in such cultures, foremost among the advantages being the facility with which transpiration as a determination of growth may be measured, the more normal development of the root system, and the economy of space.

A disadvantage was found in a submerged culture, such as rice, in the danger of leakage liable from the puncture of the frail paraffin covering of the pots. The experiment, however, proved the adaptability of the method, and it was found that the measure of growth as determined by the amount of water transpired by the plants approximated closely the relative weights of the plant in the green and moisture-free conditions.

---

[a] U. S. Dept. Agr., Bur. Soils Circs. 15, 18; Rhode Island Sta. Buls. 109, 120; Ohio Sta. Bul. 168.

The pots being very small, only 3 inches in diameter and 3 inches deep, the plants could not be grown to maturity, so a period of about thirty days' growth was fixed as the limit, and five rice seedlings were placed in a pot. It has been pointed out,[a] and is also the common observation, that decided soil deficiencies are indicated by the crop long before it has reached its maturity. In so far as a crude but rapid determination of the immediate manurial requirements of the soil is useful as a guidance for further experiment, the wire-pot method commends itself to workers along these lines.

EXPERIMENT I.

This experiment was carried out on lines set forth in Circular 18 of the Bureau of Soils, except that the optimum moisture condition of the soil was made complete saturation, or slightly in excess. This was necessary to supply as normal a condition as possible for rice culture. The soil of the trial grounds was selected for this and most of the subsequent experiments, not because it was typical of the large area of rice lands in the islands, but because it lent itself to a great range of artificial modifications.

A composite sample of the soil was taken, thoroughly mixed and pulverized, after which various fertilizers were added, the amounts used approximating those employed in ordinary field practice. The fertilizers added were dry manure at the rate of 5 tons per acre; lime, 1 ton; nitrate of soda, 200 pounds; sulphate of potash, 200 pounds; acid phosphate, 200 pounds; nitrate of soda and sulphate of potash, 200 pounds each; nitrate of soda and acid phosphate, 200 pounds each; sulphate of potash and acid phosphate, 200 pounds each; nitrate of soda, sulphate of potash, and acid phosphate, 200 pounds each; nitrate of soda, sulphate of potash, and acid phosphate, 200 pounds each, to which was added lime, 2,000 pounds; and nitrate of soda, 200 pounds, applied in ten doses at three days' interval. After mixing the fertilizer with the soil it was allowed to stand for several days, when the baskets were filled and the pots arranged in twelve series, each series containing four pots.

Carefully selected one-week-old seedlings of the Hawaiian Gold Seed were used in this experiment, and after they had attained a height of about 1 inch, five seedlings were transplanted to each pot and permitted to attain a growth of 2 inches. The optimum moisture condition having been provided, the pots were sealed over, weighed, and photographed on August 15. From this date they were weighed at three-day intervals until the termination of the experiment, which in most cases was thirty days.

[a] Rhode Island Sta. Bul. 109.

A summary of the results obtained is given in the accompanying table:

Summary of pot experiments with rice, showing effect of fertilizers on growth.

Series No.	Fertilizer used and calculated rate per acre.	Water transpired by 5 plants in total period of growth.	Green weight of 5 plants at end of 30-day period.	Water-free weight of 5 plants at end of 30-day period.	Water transpired per pound of water-free substance.
		Grams.	*Grams.*	*Gram.*	*Pounds.*
1	Check (no fertilizer)	202.0	1.92	0.42	480.95
2	Stable manure, 5 tons	287.4	2.75	.60	479.00
3	Lime, air-slaked, 1 ton	296.3	2.75	.57	519.82
4	Nitrate of soda, 200 lbs.	276.1	2.57	.57	484.38
5	Sulphate of potash, 200 lbs.	298.1	2.75	.57	522.98
6	Acid phosphate, 200 lbs.	276.7	2.57	.57	485.44
7	Nitrate of soda and sulphate of potash, 200 lbs. each	299.7	2.47	.60	499.50
8	Nitrate of soda and acid phosphate, 200 lbs. each	292.9	2.67	.57	513.86
9	Sulphate of potash and acid phosphate, 200 lbs. each	235.1	2.37	.50	450.50
10	Nitrate of soda, sulphate of potash, and acid phosphate, 200 lbs. each	314.6	2.67	.60	524.33
11	Nitrate of soda, sulphate of potash, and acid phosphate, 200 lbs. each, and lime, 2,000 lbs.	273.3	2.50	.55	496.91
12	Nitrate of soda, applied in 10 doses, 3 days apart, 200 lbs.	420.2	4.40	.95	442.10

In the above table the first column gives the amount of water transpired, the second the green weight of the five plants at the end of the experiment, the third the dry weight of the plants, and the fourth the amount of water transpired for each pound of water-free substance produced. This last column, which is the result of computing the other data, shows that the rice plant during the first thirty days of its growth transpires approximately 500 pounds of water to every pound of dry material produced. The smallest proportionate transpiration occurred in the series receiving nitrate of soda at intervals during the experiment, and this series also produced the greatest growth. The next lowest transpiration was found in the series receiving sulphate of potash and acid phosphate.

The most striking result obtained in this experiment was the superior growth obtained where the nitrate of soda was supplied in ten equal doses. The results obtained in this series if compared with the series in which the same amount of nitrate of soda was applied all at one time show marked contrast. The second important result of this experiment is shown in the series where a ton of lime was added to the complete fertilizer. This apparently depreciated the yield below the unlimed series fully 10 per cent. These results are not confirmed in the series which received lime only, but subsequent field experiments strongly emphasized the fact that lime had a depressing effect upon the crop, in the yield of both grain and straw.

The other treatments appeared to exercise a beneficial influence upon the growth of the seedlings, but the results are such as not to

permit of definite conclusions. The least beneficial results were obtained where a combination of potash and acid phosphate was used. In subsequent experiments these two substances gave maximum yields from much smaller applications.

EXPERIMENT II.

The object of this experiment was to determine, so far as possible, by means of pot cultures, the influence upon the yield of grain and straw of the various elements found in commercial fertilizers, used in combination with and without lime. It was planned to grow the plants to maturity, hence larger pots were necessary than those afforded by the paraffined wire-pot method, and glass jars holding 2½ kilograms of dry soil were substituted. Three jars constituted a series. One received an application of lime in addition to the regular fertilizer, the other two remained unlimed. One of these was devoted to a lysimeter experiment, the results of which were too inconclusive for publication. A duplicate of this experiment is under way.

To each pot six selected seedlings of Japan variety No. 153 were transplanted. The soil used was that from the trial grounds, the same as in Experiment I, except that a crop of rice had been harvested since the first experiment. All the fertilizers were mixed with the soil before planting and were contained within the first 3 inches of the soil. The fertilizers were applied at the rate of 50 pounds per acre for each element.

The results of this experiment were not recorded in actual weights, but marked differences were noted in the appearance of the plants at the end of the experiment. One of the striking results obtained was the general depression of the plants when treated with lime, the loss amounting to from 14 to 40 per cent. Subsequent field trials confirm these results. S. Suzuki[a] suggests that the injurious effect of lime may be due to the neutralization of the acids exuded by the roots, in consequence of which less food becomes available to the plants. The depressing effect of liming rice soils is recognized in Japan. Dr. T. Nakamura informed the writer that the liming of rice soils in the Kiushu district of Japan is prohibited by law.

The general results of this experiment indicate that nitrogen in the form of sulphate of ammonia is especially suitable for the rice plant, and this fact was further borne out in plat experiments and also when tried on a field scale in a different locality. Where the nitrogen was supplied in the form of fish guano, the results agreed closely with those obtained where sulphate of ammonia was used. Next to the beneficial results obtained from nitrogen in the form of sulphate of ammonia and fish guano, acid phosphate seems to be the most avail-

[a] Bul. Col. Agr., Tokyo Imp. Univ., 6 (1905), No. 4, pp. 347–351.

FIG. 1.—COMPARISONS OF GOLD SEED AND JAPAN RICE. JAPAN SEED ON RIGHT, GOLD SEED ON LEFT.

FIG. 2.—SHOWING METHOD OF IRRIGATING FERTILIZER PLATS.

able for the rice plant. The best combination of the two elements was distinctly in favor of nitrogen and phosphorus in the form of sulphate of ammonia and acid phosphate and fish guano and acid phosphate, the two combinations being of about equal value. Next to these combinations fish guano and sulphate of potash, sulphate of ammonia and Thomas slag, fish guano and Thomas slag, sulphate of ammonia and sulphate of potash, and fish guano and muriate of potash gave results in about the order named. Where a complete fertilizer made up of the several forms of these different fertilizers was used, practically all the plants were killed within a month.

EXPERIMENT III.

The object of this experiment was to determine the relative value of different fertilizers when applied to two widely different types of rice—the Hawaiian Gold Seed, a heavy-strawed, slow-maturing, starchy rice, the standard used by the Chinese, and the dwarf, early maturing, glutenous Japan rice, largely used by the Japanese (Pl. VIII, fig. 1). The field selected for this experiment had been devoted to rice culture for a number of years without any fertilization and it had uniformly produced a fair crop, the stand being characterized by an exceptional evenness of growth. A further advantage of this locality was an ample supply of pure artesian water and a fairly well sheltered location (Pl. VIII, fig. 2).

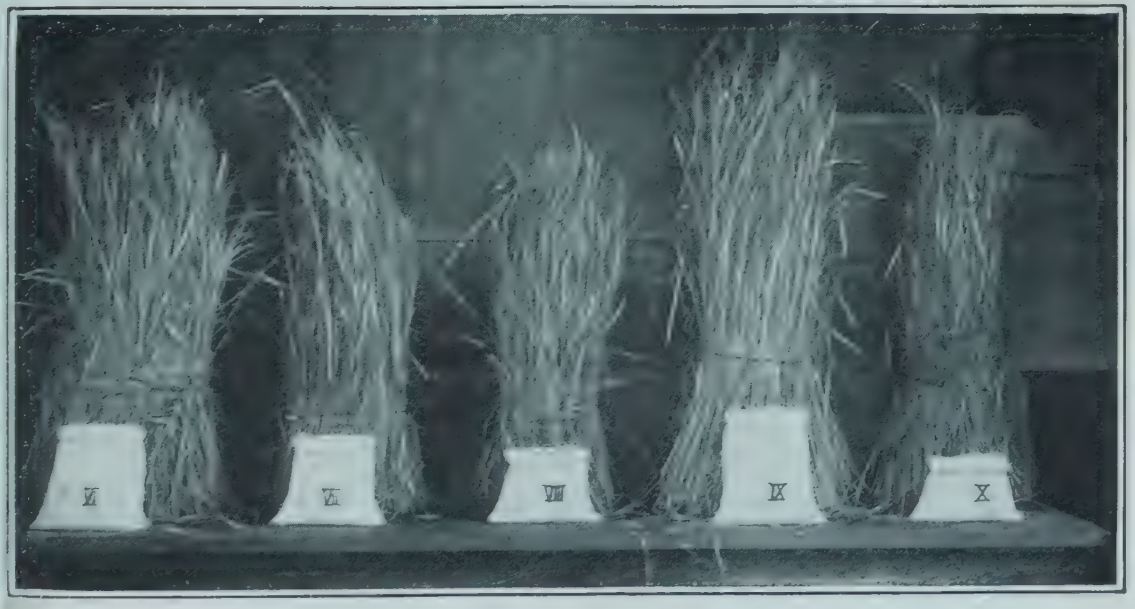
The fertilizers were supplied in as varied selection as the market afforded and such as can always be obtained in Honolulu. Where single constituents were added the amounts supplied in the fertilizer tests were 40 pounds of nitrogen, 25 pounds of phosphoric acid, and 45 pounds of potash, these quantities being based upon the plant food ingredients removed by a good crop of rice.

Each plat was divided into four sections. One was untreated, the second fertilized before planting, the third fertilized before planting and in addition limed at the rate of 750 pounds of air-slaked lime per acre, and the fourth was fertilized after the plants were three-fourths grown. Where the fertilizers were applied before planting they were worked into the dry soil and the soil left for one week, when the seed was drilled to a depth of 1 inch in rows 12 inches apart. Immediately after planting the plats were lightly flooded and the water at once permitted to recede.

Each plat was sown with two varieties of rice, the Hawaiian Gold Seed (No. 148) and the Japan Seed (No. 153). When the seedlings were 3 inches high they were thinned so as to stand 3 inches in the row, and the plats again flooded and the water allowed to cover the surface of the soil until nearly harvest.

The influence of lime in connection with and without the addition of fertilizers was determined. The uniformly negative results obtained from liming, while they can not be taken as a criterion for all rice soils, seem to show the error in indiscriminately recommending liming for all rice lands. Hawaiian rice lands are submerged for the greater part of the year, but only one out of six typical rice areas showed an acid reaction, and it is probable that this soil would have been benefited by liming.

The effect of the different treatments on the yield of Japan rice is shown in the accompanying table (see also Pl. IX).



EFFECT OF DIFFERENT FERTILIZERS ON YIELD OF JAPAN SEED PADDY AND STRAW.

[Numbers on bags correspond with plat numbers in table.]

Relative value of the various commercial forms of nitrogen, phosphoric acid, and potash as fertilizers for the rice crop.

Plat number.	Fertilizer applied.	Amount per acre.	Equivalent.	Check (untreated).				Fertilized before planting.				Limed (750 lbs.) and fertilized before planting.				Fertilized after plants were three-fourths grown.			
				Paddy.	Sterile glumes.	Straw.	Average of 10 plats.	Paddy.	Sterile glumes.	Straw.	Paddy, gain (+) or loss (−).	Paddy.	Sterile glumes.	Straw.	Paddy, gain (+) or loss (−).	Paddy.	Sterile glumes.	Straw.	Paddy, gain (+) or loss (−).
		Lbs.	*Lbs.*	*Lbs.*	*Gms.*	*Lbs.*	*Lbs.*	*Lbs.*	*Gms.*	*Lbs.*	*Per ct.*	*Lbs.*	*Gms.*	*Lbs.*	*Per ct.*	*Lbs.*	*Gms.*	*Lbs.*	*Per ct.*
1	Nitrate of soda	266	40 N	3.54	56	4.55		4.76	28	5.21	+ 25.92	3.18	85	4.20	−15.87	5.06	157	8.03	+33.33
2	Sulphate of ammonia	200	40 N	3.66	61	4.80		7.12	63	9.15	+ 88.36	3.37	105	4.68	−10.84	5.34	168	8.41	+41.27
3	Sulphate of potash	95	45 K_2O	3.93	59	5.20		10.15	84	13.09	+168.52	2.87	294	6.56	− 24.07	2.90	84	5.08	− 23.27
4	Sulphate of potash and magnesia	180	45 K_2O, 61 $MgSO_4$	3.81	44	5.55		9.06	112	12.81	+139.68	3.75	168	6.01	− 0.79	3.47	28	4.87	− 8.20
5	Acid phosphate	125	25 P_2O_5	4.02	70	6.10		8.75	119	13.15	+131.48	2.15	217	5.44	−43.12	4.59	94	6.98	+21.42
6	Reverted phosphate	156	25 P_2O_5	3.90	73	5.25		6.31	172	14.78	+ 66.93	2.06	112	3.81	−45.50	3.12	52	5.62	−17.46
7	Thomas slag phosphate	156	25 P_2O_5, 62 CaO	4.26	60	5.76	Paddy 3.78 Straw 5.29	5.56	42	7.50	+ 47.07	2.75	147	5.43	−27.25	3.12	28	5.01	−17.46
8	Complete fertilizer (nitrate of soda, acid phosphate, and sulphate of potash)	350	28 N, 17.5 P_2O_5, 31.5 K_2O	3.75	62	5.20		4.75	35	5.56	+ 25.66	3.12	140	4.48	−17.46	3.70	42	5.46	− 2.11
9	Complete fertilizer (sulphate of ammonia, fish guano, reverted phosphate, and sulphate of potash)	350	28 N, 17.5 P_2O_5, 31.5 K_2O	3.66	56	5.80		7.55	91	13.10	+ 99.73	3.37	103	3.93	−10.84	3.57	88	6.26	− 5.55
10	Complete fertilizer (nitrate of soda, Thomas slag phosphate, and sulphate of potash and magnesia)	350	28 N, 17.5 P_2O_5, 31.5 K_2O	3.30	51	4.50		3.94	49	5.31	+ 4.23	3.00	63	3.75	−20.63	4.31	49	5.27	+14.02

In reviewing the figures it appears that the average production of the ten untreated plats was 3.78 pounds of paddy and 5.29 pounds of straw. The greatest gain in paddy from any one fertilizer when applied before the crop was planted was from sulphate of potash, which yielded a gain of 168 per cent over the untreated plats, an equivalent of 2,522 pounds of paddy per acre. This additional yield, valued at $2.50 per 100 pounds, represents an increased value of $63, produced at a cost of less than $5 for fertilizer. The next largest increase in yield was on plat 4, to which the double phosphate salts were added; the acid phosphate came next, the complete fertilizer composed of sulphate of ammonia, fish guano, reverted phosphate, and sulphate of potash next, followed by sulphate of ammonia, reverted phosphate, Thomas slag, nitrate of soda, etc. While all the fertilizers produced some gain, the experiment shows the importance of the particular form in which the different constituents are supplied.

Where the fertilizers were applied after the plants were three-fourths grown, as is the general Hawaiian practice, radically different results were obtained. As might have been expected, the nitrate of soda was more effective than where applied before planting, especially in the increase of straw. On the other hand, the slowly acting sulphate of ammonia showed a decrease in yield when the fertilizer was supplied during the growing period. All forms of potash appeared to have exerted a detrimental effect and the different forms of phosphate showed a considerable decrease as compared with the same fertilizers when added before planting. As in the other experiments, the addition of lime depressed the yield of grain in all cases and in many instances the amount of straw also.

In a second experiment, in which the Hawaiian Gold Seed variety of rice was used, results almost identical with those given in the above table were obtained. The greatest benefit was secured from the use of sulphate of potash when fertilizers were applied before planting, the benefits of the remaining treatments being about in the same order as described for the treatment with Japan rice. Two notable exceptions, however, were observed. The reverted phosphate gave only 66 per cent gain over the untreated plat with the Japan Seed, while the gain for the Gold Seed amounted to 132 per cent. In a similar way the complete fertilizer used on plat 10, which gave only 4 per cent increase with the Japan Seed, showed an increase of 86 per cent for the Gold Seed. These increases may possibly be explained by the fact that the season of growth of the Gold Seed is fully forty days longer than that of the Japan Seed, and it is reasonable to believe that this additional growing period rendered available a proportionate additional amount of the slowly soluble constituents in these forms of fertilizers.

In comparing the limed section in this experiment with the experiment with the Japan rice it was noticed that a less depressing effect was exerted on the slower growing variety, although a considerable decrease as compared with the corresponding plats not limed was apparent.

Where the plants were fertilized when they were two-thirds grown practically the same beneficial effects for nitrate of soda and sulphate of ammonia were noted for both varieties of rice. The sulphate of potash, which slightly decreased the yield of Japan Seed when applied after the crop was well advanced, appeared to exert a slight benefit on the later maturing Gold Seed variety. Slightly beneficial effects were also obtained from the acid phosphates, reverted phosphates, and complete fertilizers.

EXPERIMENT IV.

Less than a decade ago practically the only fertilizers used in Hawaiian rice culture were fish refuse (fish guano and shrimp skins), Chinese peanut cake, and stable manure, the first two being imported either from China or from California in large quantities. At present stable manure is about the only material used, the high price of importations from China and the scarcity of materials elsewhere prohibiting their general use. The beneficial effect resulting from this class of manures is often commented upon by Chinese rice growers, and it was on this account that an experiment was planned to compare the value of these old-time fertilizers with the modern commercial manures.

Accordingly plat experiments were carried out with Japan Seed rice, using the materials available at Honolulu at the time. These were Chinese peanut cake, fish guano, and stable manure. The shrimp skins, once so largely used, were unobtainable, and a much-advertised and largely used commercial fertilizer was substituted. Owing to its concentration and extreme solubility it was thought that such material might possess useful features if produced cheaply enough.

A partial analysis of the fertilizing materials was made by the station chemist, and showed that the horse manure contained 0.41 per cent of nitrogen, 0.507 per cent of phosphoric acid, and 0.471 per cent of potash, and the fish guano 8.58 per cent of nitrogen and 6.95 per cent of phosphoric acid. The analysis of the commercial fertilizer was furnished by the manufacturer, and it is claimed that the substance contains 15 per cent of nitrogen, 5 to 6 per cent of water-soluble phosphoric acid, and 3 to 4 per cent of potash.

As in the previously described experiments, each plat received different treatments, some being fertilized before planting and others

when the plants were two-fifths grown. On some plats lime was used, while on others it was omitted.

As in practically all the other experiments, the addition of lime seemed to exert a depression in the yield of the crop, except on the plat receiving stable manure at the rate of 5 tons per acre.

In comparing the relative value of the application of fertilizers before sowing the crop with the results obtained where the fertilizers were applied after the crop had become well advanced, there appeared to be little difference so far as the experiments with Chinese peanut cake were concerned, but since the results in either case were poor, no weight is attached to this part of the experiment. On the other hand, the fish guano showed a decided gain in the application made before the crop was sown. This was also true of the commercial fertilizer.

In comparing the relative value of the several fertilizing materials, stable manure showed an increase of 121 per cent of paddy for an application of 2½ tons per acre, while an application of 5 tons per acre yielded 250 per cent increase over the check and over 100 per cent more than the section receiving half as much manure. The application of stable manure also greatly increased the yield of straw in proportion to the amount of grain. Next in value to the stable manure was the fish guano, which gave an increased yield of 118 per cent over the check plat, followed by the commercial fertilizer with an average gain of 100 per cent when it was applied at the rate of 100 pounds per acre. It was thought that the extreme solubility of the materials composing the commercial fertilizer would especially adapt it as a food stimulant in later applications, but this does not appear to hold true so far as this experiment is concerned. The late application of fish guano resulted in a considerable decrease in the yield as compared with the early application.

Comparing the results of the same treatment upon the Gold Seed variety a close agreement was found throughout the experiment.

EXPERIMENT V.

This and the two following experiments were carried on in cooperation with the Punaluu rice plantation, situated on the north side of the island of Oahu. This plantation was established in 1872, and it had been cropped twice annually until decreasing yields made rice culture on this land unprofitable except in years of exceptionally high prices. The yield from 37 acres of this tract for the 1907 spring crop amounted to 74,000 pounds of paddy, or an average of 2,000 pounds per acre. A part of this was produced on fertilized land, and a portion of the land had been fallowed for a season or two.

An acre tract of the poorest of these lands was set aside for these experiments, the object of which was to compare the relative value in economy of several complete fertilizers under different modes of

application. The fertilizers in the first experiment were applied April 30, 1907, when the crop was about half grown, and they consisted of a special fertilizer made up of fish guano, acid phosphate, and sulphate of potash and magnesia, and a regular fertilizer which is more or less commonly used, which consisted of nitrate of soda, sulphate of ammonia, acid phosphate, and muriate of potash. These compounds were used alone and, in the case of the special fertilizer, in combination with sulphate of ammonia. They were applied by broadcasting on receding water, broadcasting and working into the soil to a depth of 2 inches, and broadcasting on the dry surface before reflooding.

The yield of paddy on the untreated plats was 2,888 pounds, the highest yield ever produced on this land without the use of fertilizer. It is thought possible that this large yield may have been due to the application of fertilizers to the adjoining plats. In making comparisons, however, the actual weights of crops were taken.

Where the special fertilizer was used and worked into the ground to a depth of several inches, 58.5 per cent gain, equivalent to $29.60 net profit per acre, was obtained, the cost of the fertilizer and labor involved in working it into the ground being deducted. Where the fertilizer was not worked into the ground an increase of 42.5 per cent was obtained, representing a net profit of $20.75. From this it will be seen that at a cost of $2 for working in the fertilizer an additional profit of about $10 was obtained. The special fertilizer yielded an increase of 35 per cent when applied alone, only 17.5 per cent less than when sulphate of ammonia was added to it.

In these experiments the regular fertilizer exerted very little beneficial effect, due probably to the low nitrogen content, which is the most striking deficiency.

The residual effect of the fertilizers is shown by the striking growth of the second crop on the treated plats.

EXPERIMENTS VI AND VII.

In conjunction with Experiment V two special nitrogen fertilizing experiments were undertaken on a field scale. Two forms of nitrogen were used, sulphate of ammonia at $72 per ton and nitrate of soda at $55 per ton, these prices representing the Honolulu quotations in November, 1907.

The sulphate of ammonia was applied at the rate of 75 and 100 pounds per acre and the nitrate of soda at the rate of 100 and 150 pounds per acre. All the applications were made at the same time, when the plants were a little more than half grown. The methods of application were those usually practiced by the Chinese growers, i. e., to broadcast the fertilizer upon the receding flood water just before

the drying-off period, which in Hawaiian rice culture precedes the flowering stage of the rice plants.

The results of these experiments show that the sulphate of ammonia proved very efficient, and increases of 80 and 85 per cent were obtained from applications of 75 and 100 pounds, respectively. This gain was produced at the cost of $2.70 and $3.60 for material and resulted in a net profit of $35.15 and $36.50, respectively, for the different applications. The application of 100 pounds of sulphate of ammonia gave an increase of only 5 per cent over the application of 75 pounds per acre, amounting to a cash increase of only $1.35, which barely paid for the additional fertilizer. Where nitrate of soda was applied at the rate of 100 pounds per acre the gain was 21 per cent, equivalent to a net profit of $12. These results between the two forms of nitrogen are in practical agreement with those given in the pot experiments described above.

It seems reasonably certain from these and the other experiments that sulphate of ammonia is better suited to the rice crop than nitrate of soda, at least when both are applied in single applications to neutral soils. It is probable that better results can be obtained from nitrate of soda when it is applied two or three times during the growing season, particularly should the soils be acid. When it is remembered that the nitrogen in ammonium salts becomes available more slowly and gradually than in the nitrates and that nitrification takes place rapidly in saturated and submerged soils, there is probably a great waste when too large amounts of nitrate of soda are applied at one time, and an experiment has been planned to test this point in regard to the rice soils of Hawaii.

CULTURE EXPERIMENTS.

INFLUENCE OF AGE OF SEEDLINGS AT TIME OF TRANSPLANTING.

Throughout this report frequent reference has been made to the influence upon yield exerted by the age of seedlings at the time of transplanting. In the table on page 89 are given the results of an experiment in which seedlings 20, 25, 30, and 35 days old, respectively, were transplanted under otherwise identical conditions. All the seed had been sown on February 27 and the seedlings began to appear above ground on March 2.

The yield of Japan seed rice (No. 153) as influenced by age of seedlings at time of transplanting.

Experiment No.	Age of seedlings at time of transplanting.	Date of transplanting.	Date of flowering.	Date of maturity and harvest.	Yield from three 100 square feet cuttings.		Relative yields, experiment 1 taken as 100.	Calculated yields per acre.		Value of paddy per acre.[a]
					Paddy.	Straw.		Paddy.	Straw.	
					Lbs.	*Lbs.*		*Lbs.*	*Lbs.*	*Dollars.*
1	20 days old	Mar. 22	May 8	June 10	29.00	27.75	100	4,205	4,024	105.12½
2	25 days old	Mar. 27	...do	...do	25.50	24.50	87.93	3,697	3,553	92.42½
3	30 days old	Apr. 1	May 6	...do	22.25	22.50	76.72	3,126	3,263	78.15
4	35 days old	Apr. 6	May 5	...do	13.25	18.00	45.69	1,921	2,610	48.02½
5	20 days old (fertilized) ..	Mar. 22	May 9	...do	32.50	48.00	112.07	4,713	6,960	117.82½

[a] At $2.50 per 100 pounds.

By referring to experiment 1 it will be seen that the maximum yield was obtained from seedlings 20 days old at the time of transplanting and that a gradual and considerable decrease in yield resulted from each subsequent transplanting, the yields being almost in a direct diminishing ratio to the increased age of the seedlings. The importance of this phase of rice culture wherever the crop is transplanted, as it is in Hawaii and Oriental countries generally, can not be too strongly dwelt upon, since 10 days' delay in transplanting seedlings may decrease the yield of paddy almost one-half. It is to be remembered, however, that this loss, at least in this experiment, applies particularly to the quick-maturing varieties. Much less striking results were obtained from a preliminary experiment with a Hawaiian type of rice that required 140 days for maturity. The loss in yield due to the increased age of the seedlings at the time of transplanting was less than half that reported for the Japan type.

It will be noted in experiment 5 that in addition to being planted with 20-day-old seedlings the plat received 350 pounds of complete fertilizer, and that this addition resulted in increasing the yield only 12 per cent over the unfertilized plat. A part of each of the other plantings was likewise fertilized, and this resulted in a considerably greater gain in the plats planted to 25 and 30 day old seedlings. It is believed that the older seedlings having had their growth retarded were more largely influenced by the fertilizer than those which were transplanted at a more favorable season.

EXPERIMENTS IN BROADCASTING, DRILLING, AND TRANSPLANTING RICE.

An experiment was undertaken to test the relative value for Hawaiian conditions of two distinct methods of planting—the direct sowing of seed, as practiced in the southern United States, and the Hawaiian and Oriental custom of transplanting the seedlings. All the seed was sown on February 27. One lot was broadcasted at the

rate of 50 pounds per acre and another lot of the same stock of seed drilled in rows 12 inches apart at the same rate per acre. When well established the seedlings in both cases were thinned out to a stand of approximately 200,000 plants per acre, to conform as closely as possible with the stand of transplanted plants.

The results of this experiment are shown in the accompanying table:

Relative yields from broadcasted, drilled, and transplanted Japan seed rice (No. 153).

Experiment No.	Method of culture.	Date of germination.	Date of flowering.	Date of maturity and harvest.	Height of plants.	Average number of fruiting culms per plant.	
						Primary.	Secondary.
1	Seed broadcasted, harrowed in 1 to 2 inches deep, and flooded	Mar. 2–5	May 1–5	June 6	*Inches.* 23–24	2–3	1–2
2	Seed drilled in 1 to 2 inches deep (rows 12 inches apart) and flooded	....do	.....do	....do	25–28	2–3	1–2
3[a]	Seedlings 20 days old at transplanting	Mar. 2	May 8–10	June 10	32–34	6–8	1–3
4[a]	Seedlings 35 days old at transplanting	....do	May 3–5	....do	20–22	2–4	1–2

Experiment No.	Method of culture.	Yield from three 100 square foot cuttings.		Calculated yields per acre.		Value of paddy per acre.[b]
		Paddy.	Straw.	Paddy.	Straw.	
1	Seed broadcasted, harrowed in 1 to 2 inches deep, and flooded	*Pounds.* 12.25	*Pounds.* 17.95	*Pounds.* 1,776	*Pounds.* 2,501	*Dollars.* 44.40
2	Seed drilled in 1 to 2 inches deep (rows 12 inches apart) and flooded	13.50	15.50	1,958	2,393	48.95
3[a]	Seedlings 20 days old at transplanting	29.00	27.75	4,205	4,024	105.12½
4[a]	Seedlings 35 days old at transplanting	13.25	18.00	1,921	2,610	48.02½

[a] Taken from preceding table. [b] At $2.50 per 100 pounds.

It will be seen from experiment 3 that the seedlings 20 days old at the time of transplanting yielded more than either the broadcasted or drilled seed, the increased cash value being more than $50 per acre for the transplanted stock. On the other hand, when the seedlings were 35 days old at the time of transplanting the yields were about equal to those from direct sowing.

The differences in yield due to broadcasted or drilled seed are hardly sufficient to warrant definite conclusions. It is believed, however, that greater uniformity of stand and economy of seed are obtained by drilling.

The cost of transplanting an acre of rice in Hawaii does not exceed $6. Four men can transplant an acre per day, setting out 50,000 clumps, consisting of from 4 to 8 seedlings each.

From the above table it is readily seen that under present Hawaiian conditions the transplanting method in rice culture is amply justified.

O

HAWAII AGRICULTURAL EXPERIMENT STATION

E. V. WILCOX, SPECIAL AGENT IN CHARGE.

ANNUAL REPORT

OF THE

HAWAII AGRICULTURAL EXPERIMENT STATION

FOR

1908.

UNDER THE SUPERVISION OF

OFFICE OF EXPERIMENT STATIONS.

U. S. DEPARTMENT OF AGRICULTURE.

HONOLULU:
HAWAIIAN STAR PRINT.
1909.

HAWAII AGRICULTURAL EXPERIMENT STATION, HONOLULU.

[Under the supervision of A. C. TRUE, Director of the Office of Experiment Stations, United States Department of Agriculture.]

WALTER H. EVANS, *Chief of Division of Insular Stations, Office of Experiment Stations.*

STATION STAFF.

E. V. WILCOX, *Special Agent in Charge.*
D. L. VAN DINE, *Entomologist.*
J. E. HIGGINS, *Horticulturist.*
F. G. KRAUSS, *In Charge of Rice Investigations.*
W. P. KELLEY, *Chemist.*
ALICE R. THOMPSON, *Assistant Chemist.*
C. J. HUNN, *Assistant Horticulturist.*
D. T. FULLAWAY, *Assistant Entomologist.*
Q. Q. BRADFORD, *Assistant in Rubber Investigations.*

LETTER OF TRANSMITTAL

HAWAII AGRICULTURAL EXPERIMENT STATION,
Honolulu, Hawaii, January 4, 1909.

SIR: I have the honor to transmit herewith and to recommend for publication the Annual Report of the Hawaii Agricultural Experiment Station for the fiscal year 1908.

Respectfully,

E. V. WILCOX,
Special Agent in Charge.

DR. A. C. TRUE,
Director Office of Experiment Stations,
U. S. Department of Agriculture, Washington, D. C.

Publication recommended.
A. C. TRUE, *Director.*

Publication authorized.
JAMES WILSON,
Secretary of Agriculture.

CONTENTS.

	Page.
Summary of investigations	9
Chemical investigations	10
Rubber	11
Entomological investigations	11
Horticultural investigations	12
Rice investigations	14
Experiments with matting sedges and rushes	15
Cotton experiments	15
Miscellaneous crops	16
Report of the entomologist	17
Introduction	17
The horn fly (*Haematobia serrata*)	18
The sheep-maggot fly (*Calliphora dux*)	21
Bee keeping	23
The source of honey in the Hawaiian Islands	24
Pineapple insects	27
Mosquitoes	28
A revised list of the injurious insects of Hawaii	29
Crops	29
Fruits	32
Ornamental plants	34
Forest trees	35
Live stock	36
Household insects	37
Stored products	37
Accessions to entomological library relating to Hawaiian entomology	38
Report of the horticulturist	42
Shipping tropical fruits	42
The orchards	42
Tillage and irrigation	42
Cover crops	42
Orchard insects	43
The citrus orchard	44
Bananas	44
Mangoes	45
Budding	45
Transplanting	46
Inarching	46
Shipping by mail	47
Flowering season	47
Bordeaux mixture for blight	47
Plant acquisitions	48
Plants distributed	49
Miscellaneous	50

Page.

Report of the assistant chemist 51
Chemical studies of rice and rice products 51
Miscellaneous fodders 58
Fertilizer analyses 60
Soils 61
Water analyses 62
Miscellaneous work 62
Field crop experiments 65
Rice investigations—Report of second year's experiments .. 65
Introduction 65
The milling industry 65
Comparative test of old and new varieties of rices 67
Fertilizer experiments 70
Experiment 1. Residual fertilizer experiment (a) .. 70
Experiment 2. Residual fertilizer experiment (b) .. 73
Experiment 3. Direct fertilizer experiments 75
Experiments 4 and 5 76
Fertilizer experiments on dry-land rice 78
Cooperative experiments with a complete fertilizer. 78
Upland rice as a hay and grain crop 79
Salt-marsh rice as hay 81
Chinese and Japanese mat rush experiments 82
Cotton experiments 82
Soy beans 83
Peanuts 84
Leghorn wheat 84

ILLUSTRATIONS.

		Page.
PLATE I.	New insectary built on sewer pipe piers resting in cement basins filled with water	12
II.	General view of mango and avocado orchard	45
III.	Fig. 1.—A budded mango tree, 7½ months after the setting of the bud. Fig. 2.—Mangosteen (*Garcinia mangostana*)	47
IV.	Fig. 1.—Uniform planting scheme in rice experiments. Fig. 2.—Seven types of Japan rice	67
V.	Fig. 1.—Relative growth produced from equal amounts of nitrogen. Fig. 2.—Harvesting salt-marsh rice for hay	70
VI.	Fig. 1.—*Cyperus tegetiformis* (Chinese mat rush) five months from planting. Fig. 2.—Caravonica tree cotton at the Hawaii Experiment Station	81
VII.	Fig. 1.—Plat of soy beans. Fig. 2.—Dwarf soy beans, used as shell beans in making "miso" and other Japanese food products	84

ANNUAL REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION FOR 1908

SUMMARY OF INVESTIGATIONS.

By E. V. Wilcox, *Special Agent in Charge.*

The investigations described in the accompanying report were all begun under the supervision of the former special agent in charge, Mr. Jared G. Smith, who severed his connection with the station at the end of the fiscal year. The report, however, was prepared under the direction of the present special agent.

During the year considerable attention was given to the improvement of the general appearance of the station grounds and buildings. A number of old and unsightly structures were torn down and replaced by others more serviceable and of better appearance. One structure was erected to contain a tool house, seed storehouse, and carpenter shop, on the ground floor, and a rice laboratory in the second story. An addition was made to the stable, in which a blacksmith shop and implement shelter are provided. The experimental grounds and pastures were surrounded with new and substantial fences, and about 5,000 feet of new pipe line was laid for irrigation purposes. In addition to these changes and alterations, an old office building was torn down, and a new 5,000 gallon water tank was erected near a 2-acre rubber plantation on the slope of Tantalus at an elevation of about 700 feet.

The leases held by the station on lands for growing rice, cacao, and bananas have been given up, except for the rice trial fields, which are conveniently situated and are in excellent tilth. The other leases were abandoned on account of the distance of the lands from Honolulu and the difficulty of supervising the experiments under the present appropriation.

During the year the station published Press Bulletin No. 20, on The Introduction of Top-Minnows into the Hawaiian Islands, by D. L. Van Dine, and the following Bulletins, in the regular series of the station: No. 14, Marketing Hawaiian Fruits, by J. E. Higgins; No. 15, Cultivation of Tobacco in Hawaii, by Jared G. Smith and C. R. Blacow; No. 16, The Ceara Rubber Tree in Hawaii, by Jared G. Smith and Q. Q. Bradford; and No. 17, Hawaiian Honeys, by D. L. Van Dine and Miss Alice R. Thompson.

The correspondence of the station related chiefly to the supervision of field experiments, the distribution of economic plants to the islands, the introduction of new plants or varieties, advice regarding cultural details of various crops, the control of insect and fungus enemies, and suggestions to prospective settlers in reply to inquiries regarding prospects for farmers in these islands. Various localities on all of the important islands were visited during the year by the station staff, and the horticulturist made a trip to the mainland in the investigation of fruit shipping. The station assisted in a horticultural and agricultural exhibit in coöperation with the Hawaiian Poultry Association. Members of the station staff also gave lectures at meetings of the farmers' institute and in connection with the work of the College of Hawaii.

CHEMICAL INVESTIGATIONS.

The principal chemical work of the year was of an analytical nature and was concerned chiefly with the determination of the composition of paddy, rice straw, and rice grain. This work was done in coöperation with the rice investigations of the station. Analyses were made of several varieties of rice, particularly imported Japan rice, Japan rice grown in Hawaii, and Hawaiian Gold Seed rice. The analyses showed that the claims which have been made for the greater nutritive value of imported Japan rice, as compared with Japan rice grown in Hawaii, are not well founded. In fact, Japan rice grown in Hawaii appears to be slightly more nutritious than that imported directly from Japan. The composition of rice straws is not quite so constant as that of rice grain. It was found that dry-land rice takes up less lime and more phosphoric acid than rice grown under submerged conditions.

Analyses were also made of rice hay as fodder, Rhodes grass, cassava waste, wheat hay, cowpea, jack bean, pigeon pea, castor pomace and peanut meal. In connection with pineapple investigations, analyses were made of soils from pineapple fields. As a rule, the lime content was found to be low. Potash and available phosphoric acid were also somewhat deficient. In some cases, the lime content was higher than that of magnesia, while in other cases the conditions were reversed.

Analyses of drainage water, from lysimeter experiments, showed that the use of ammonium sulphate as a fertilizer causes loss of lime in the soil. Analyses were made of wax left in slum-gum and also of koa bark and ohia bark. In a pot experiment with fertilizers for Hevea rubber, it was found that sodium nitrate gives good results, while acid phosphate affects rubber trees unfavorably.

RUBBER.

The chief results from the rubber investigations of the year were published in Bulletin 16. During the last quarter of 1907, experiments were made in planting Hevea rubber seeds. They germinated and grew best when the shell had been removed and the seeds planted in clean sand. The herring-bone system of tapping on Ceara rubber trees gave quite favorable results. In some experiments on Kauai it was at times found difficult to coagulate the latex. This was accomplished, however, by the addition of hydrogen peroxide and sulphuric acid. As many as thirty consecutive tappings were made by excising a thin slice of bark from the old wound, and a good flow of latex was obtained during the whole period. The use of a water bag, or an ammonia bag, was found to increase the relative amount of first-grade rubber as compared with scrap rubber. By tapping yearling trees it was found that the yield differed greatly. This point may be of value in indicating which trees should be cut out, and which ones should be kept in the plantation to increase the total yield.

ENTOMOLOGICAL INVESTIGATIONS.

The insect collection and reference library have been considerably increased and a steady improvement has been made in the systematic arrangement of this material. The chief lines of entomological work during the year were studies of insects affecting domestic animals, pineapples, cotton, mangoes, and apiculture. A survey was made of the cattle ranges for the purpose of determining the status of the horn fly. This insect is perhaps more injurious in these islands than on any part of the mainland, occuring in immense swarms and attacking not only cattle, but also other animals. An attempt is being made to introduce natural parasites of the horn fly to supplement direct and indirect insecticidal measures, such as treatment of cattle dung and spraying infested cattle. The problem is recognized as a difficult one on account of the universal distribution of the pest in the islands and the half-wild conditions under which range cattle live. In the case of dairy herds and work oxen, the problem is somewhat simpler.

Great losses have been suffered from sheep-maggot fly (*Calliphora dux*), which has changed its habits so as to become a parasitic insect. The insect deposits its eggs on wounds, in areas infested by the sheep-scab mite, or in soiled wool. The larvae make their way into the tissues underneath the skin, causing suppuration and septicemia, followed by death, unless a suitable treatment is administered. The investigations thus far made indicate clearly that in order to control this pest it is absolutely necessary that all sheep carcasses should be promptly buried. In this way the excessive multiplication of the sheep-maggot fly

will be checked, for the favorite breeding ground of the pest is in carcasses. It has also been found necessary to destroy eggs and maggots in infested pens and corrals.

The entomologist has devoted considerable time to the investigation of apicultural problems and the encouragement of bee raising. The honey crop of the islands for the year will amount to nearly 1,000 tons. Available locations for apiaries have been largely taken up, but there is still room for extension. A survey has been made of the honey-plants of the islands and a number of new honey-plants, which are also useful for other purposes, have been introduced. The present list of good honey-plants in the islands is extensive. In order to prevent the possible introduction of foul brood, an act was passed by the Territorial legislature providing for the careful inspection of imported bees and honey.

The great extension of the pineapple industry has called attention to certain injurious insects, particularly scale insects and mealy bugs. A number of fumigation tests were made in which effective doses were determined for fumigating pineapple suckers and offsets before planting, and also for treating pineapple fruits before shipment to the mainland. As a result of the recommendations based upon these experiments, the shipment of fresh pineapples to the mainland has been accomplished with striking success.

The station has for the time closed its work in the investigation of mosquitoes, the important facts concerning their life history and suppression having been determined and published. The control of mosquitoes is now in the hands of the Territorial authorities.

A revised list has been prepared of the injurious insects of Hawaii, and also of the additions to the entomological library relating to Hawaiian entomology.

A new insectary has been erected and equipped (see Pl. I). It is built on sewer pipe piers set in cement basins filled with water. The steps are separate from the building and the building is insect proof.

HORTICULTURAL INVESTIGATIONS.

The chief work of the year was done in studying the problems of shipping fresh fruit, including pineapples, avocados, papayas and bananas. The demonstration of the possibility of shipping pineapples and avocados as far as Chicago was followed by commercial shipments to various inland cities. The great increase in the acreage of pineapples has called attention to the necessity of further developing the fresh-fruit markets, and the results thus far obtained are encouraging.

A rearrangement of water pipes in the orchards of the station has made it possible to irrigate more conveniently and satisfactorily. Much attention has been given to cover crops for

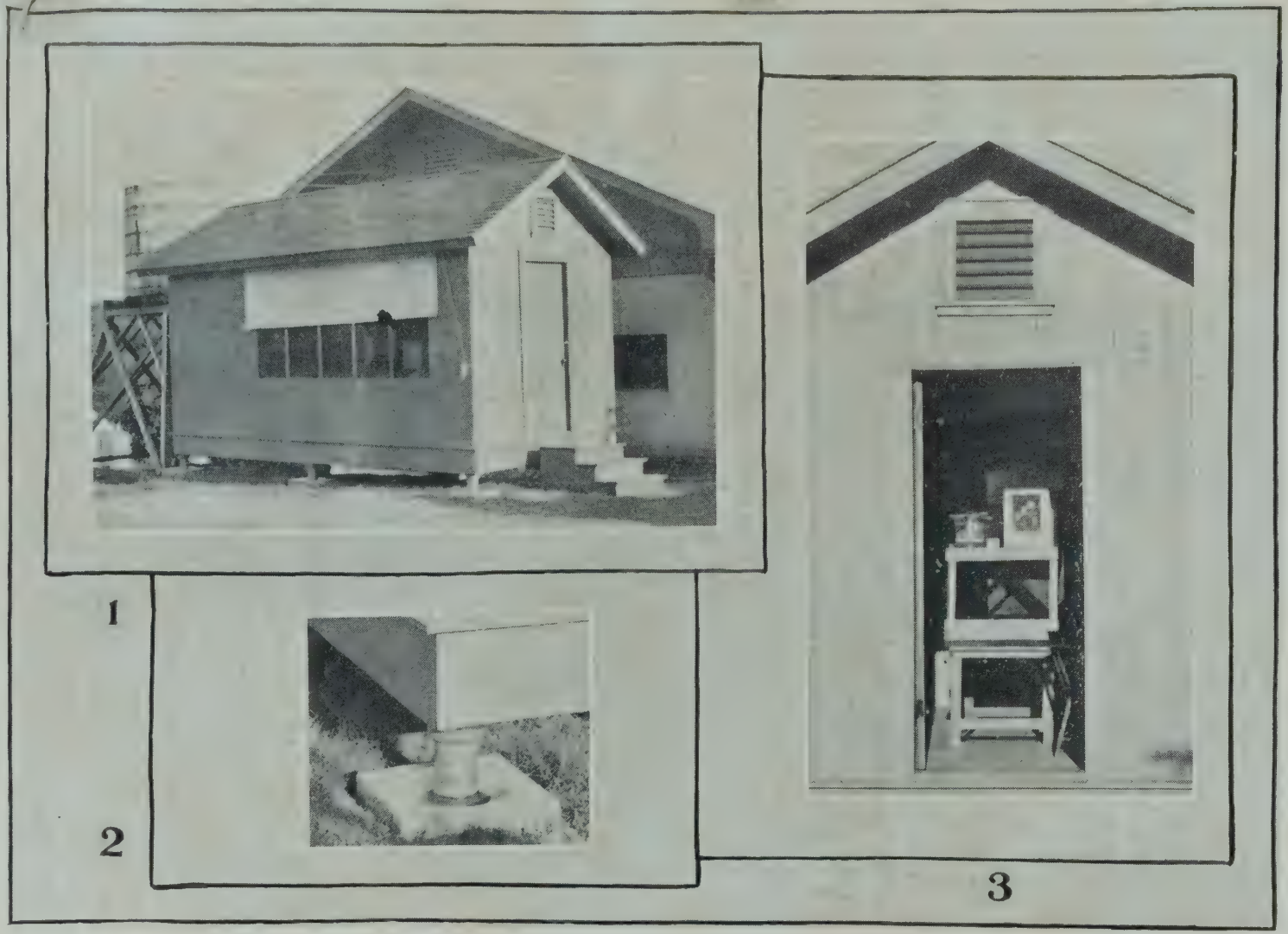


Fig. 1. New Insectary built on sewer pipe piers resting in cement basins filled with water.
Fig. 2. Detail of pier. Fig. 3: Interior showing breeding cages.

orchards. On steep grades cover crops are necessary to prevent washing during the occurrence of heavy showers. Since growth continues during the whole year, it is necessary to keep the ground free from the cover crop for a short distance around each tree. The cover crops chiefly used so far are cowpeas, pigeon peas, and jack beans. Cowpeas make the quickest growth, but are quite susceptible to the attacks of insects. Pigeon peas require longer to reach maturity. The jack bean makes a lower growth but is a good cover and is exceptionally free from insects. The ordinary insect pests have been kept in check by repeated spraying with kerosene emulsion; and by the use of a sticky mixture to keep ants from the trees.

The rough lemon has proved to be an excellent stock for use in establishing citrus orchards. An extensive budding test is in progress. More than forty varieties of bananas are growing on the station grounds. It has been found necessary to establish a nursery to supply the demands which are made for certain varieties; otherwise the experimental work would have been interfered with. Several of the varieties now grown at the station were imported from Porto Rico, and the native varieties have been collected from various parts of the Territory.

In work with mangoes, 80 per cent of the buds of Alphonse mango have grown. The results are not always so satisfactory with all varieties. It has been shown that budding must be done in the early part of the season of active growth. Mango trees two or three years old may be safely transplanted. In experiments at the station nearly all the trees transplanted at that age quickly started into growth whether the roots were freed from soil in the process of transplanting or had been enclosed in a ball of wet earth. Inarching appears to be the surest means of propagating fine varieties of mangoes, but is rather more expensive than budding. (See Plate II). In shipping experiments with young mango trees, it was found that a large percentage of them will be lost in transit unless care is taken to select trees with firm wood and a dormant terminal bud.

Attention has been given to the study of the flowering period of the mango, which appears to vary from year to year. The station has added more than three hundred varieties of plants to its horticultural collection during the year. Of this number, special mention should be made of henequen, pineapple varieties (from the Department of Agriculture), wampi fruit, cherimoya, litchi, camphor, and the Victor variety of roselle. A constantly increasing call is made for plants and cuttings for distribution in different parts of the islands; and the station has complied with these requests in so far as the facilities and experimental work would allow.

The horticulturist has given considerable attention to the encouragement of deciduous plantings at high altitudes on the island of Hawaii, and to a study of the problems connected with the production of red peppers.

RICE INVESTIGATIONS.

General interest in rice investigations is increasing from year to year, and the expert in charge of this work has been called upon for advice and technical help in the fertilization, culture, harvesting, milling, and other processes connected with rice production.

A variety known as No. 19, originally from Ceylon, has proved to be an exceptionally heavy yielder and is especially adapted as an export crop for consumption by Chinese upon the mainland. It is best used as a fall crop. Variety No. 65, an Egyptian rice, has given excellent returns in dryland culture. The yield is satisfactory. The variety promises well as a hay crop on account of its smooth glumes and large yield.

During the year an elaborate series of fertilizer experiments was carried on with rice. It was shown that when fertilizers are applied to rice after the crop is two-thirds grown the first crop receives the least benefit, and the succeeding crop shows the greatest residual effect of the fertilizer. If, on the other hand, the fertilizer is applied before planting the first crop of the season, this crop takes up nearly all of the fertilizer, while the second crop receives little or no benefit. In pot experiments it was shown that there is no residual effect of nitrate of soda upon the second crop, even though the application be made at a late stage of growth of the first crop. The greatest residual effects upon the second crop have been produced by the use of sulphate of ammonia and fish guano. Experiments in pot and field culture have demonstrated that rices which mature slowly receive the most benefit from fertilizers which become available slowly, for example, sulphate of ammonia.

In direct fertilizer experiments, in which the residual effect upon the second crop was disregarded, a comparison was made between sulphate of ammonia, lime nitrogen, and nitrate of soda. The sulphate of ammonia doubled the yield, as compared with unfertilized rice, and gave much better results than either lime nitrogen or nitrate of soda. The last named source of nitrogen appeared to give little benefit in increased growth, except when applied after the crop was two-thirds grown. In dry-land culture of rice muriate of potash produced striking results. The experimental results, obtained in pot and field cultures, have attracted much attention and the station has been called upon to plan a scheme for the systematic fertilization of a large rice plantation. This plan has already been put into effect.

The lack of natural hay crops in the islands, and the consequent heavy drain upon the resources of farmers in buying imported hay, suggested to the station the desirability of a study of upland rice as a hay crop. It has been found that $2\frac{1}{2}$ inches of water per week, during the growing season, is necessary to

insure a paying crop. Our experiments have also demonstrated the desirability of deep and thorough tillage and light seeding.

Salt marsh rice has also been tested as a hay crop. Rice grown on salt marshes is inferior in quality of grain, but has been demonstrated to be an efficient substitute for imported hays. It is believed that a portion of the $250,000 annually paid for imported hays may profitably be devoted to the production of a home crop of salt marsh rice for hay. The total weight, in a green condition, of salt marsh rice is about 14,000 pounds per acre, valued at $73. No difficulty has been experienced in securing such hay in a well cured condition. The feeding experiments thus far made with this material have shown that it is relished by cattle and horses and that its nutritive value is satisfactory.

EXPERIMENTS WITH MATTING SEDGES AND RUSHES.

For two years experiments have been carried on with Chinese mat sedge (*Cyperus tegetiformis*), and Japanese Bingo-i mat rush (*Juncus effusus*). Three harvests have been made of these matting plants at the rice trial grounds and a large planting has been made on the windward side of the island of Oahu. The yield from the Chinese mat sedge has been at the rate of 8,700 pounds per acre of the 60-inch length; 5,700 pounds of the 48 to 60-inch length; and 5,200 pounds of the 30 to 48-inch length. The crop requires from six to seven months from planting to maturity, and five months for the rattoon crop. Sample reeds of the Chinese matting sedge were forwarded to a factory on the mainland, and flattering reports were received as to their quality. A small sample of woven mat was made from the material. The greatest difficulty in the way of making this crop a financial success consists in the fact that each reed must be split. With the invention of a machine for doing this work, the crop promises to be profitable and can be grown in brackish marshes, which would otherwise be useless. The Japanese matting rush does not require splitting and is improving with each crop, but has not yet attained a sufficient length for profitable handling.

COTTON EXPERIMENTS.

Fifty years ago Sea Island cotton was grown in these islands, but the industry was allowed to lapse. The station has been experimenting with Sea Island and Caravonica cottons with striking results. The yield is high, the fiber of good length, strength and luster, and the percentage of lint ranges from 30 to 40. All varieties of cotton thus far tested grow as perennials in these islands, and the shape of the trees and the time of maturing the bolls may be controlled by pruning.

MISCELLANEOUS CROPS.

Several varieties of soy beans have been grown for use as fodder, green manuring, and human food, particularly in the Japanese product, Miso. The yields have been very encouraging. About 500 tons of soy beans are annually imported from Japan, and the demand is increasing. These beans are sold in Honolulu for $3 per 100 pounds. The market can easily be supplied by home production.

Peanuts have yielded gratifying results in various localities. On the trial grounds of the station a number of varieties have been grown, including Spanish, Bunch Jumbo, Running Jumbo, and Virginia Running.

REPORT OF THE ENTOMOLOGIST.

By D. L. Van Dine.

INTRODUCTION.

The entomologist visited during the year the islands of Hawaii, Maui, Kauai, Molokai, and all the outlying districts on the island of Oahu. Two trips were made to the island of Molokai, where the opportunity for observations on bee-keeping and live-stock insects are exceptionally favorable.

The office record relating to injurious insects in Hawaii in general and to particular groups or species in detail, the collection, and the reference library show a steady growth. This material will be so arranged that the information at hand will be available for use without loss of time, and further, so that accessions may be made without adding confusion. It is the purpose to work toward a systematic arrangement which will permit the use at any time of the results of entomological investigations throughout the world in so far as they are applicable to the peculiar climatic and economic conditions of Hawaii.

The important lines of work during the year were investigations relating to the insects affecting live stock and bee keeping. On Oahu, further work was undertaken on the insects affecting pineapples, cotton, and mangoes.

The insects affecting live stock in Hawaii are second only in economic importance to those injurious to sugar cane. Some of the species of this group of pests are known to stockmen, and the status of one especially, the horn fly, is well understood. There are several live-stock pests recorded from Hawaii the local status and occurrence of which have not been definitely ascertained, as for example the horse botfly, the stable fly, and the sheep head-maggot fly; and there are still others which are not even recorded, as the two recently determined species of blow or maggot-flies affecting sheep. An effort is being made on the natural-enemy phase of the control of the horn fly and there is a possibility of relief from this source, but the general statement can be made that as a group the insects affecting live stock in Hawaii exact their heavy annual tax unhindered and, in some instances, unrecognized.

The investigations relating to the insects affecting live stock in Hawaii were undertaken jointly by the writer and Dr. V. A. Nörgaard, Territorial veterinarian and veterinary inspector of the Bureau of Animal Industry of the U. S. Department of Agriculture. The writer is responsible for the entomological work and Dr. Nörgaard has in charge the pathological investi-

gations relating to the subject. The notes on the horn fly and the sheep-maggot fly are taken in the main from a joint report to the Hawaiian Live-Stock Breeders' Association.*

The interest at present being shown in the production of cotton in these islands will necessitate some consideration of the insects affecting the cotton plant. A large number of insects attack cotton, and the combined effect of their injuries on the growth of the plant and the quality of the staple offers a more or less serious menace to the success of cotton growing.

The worst injury is done by a small boll worm (larva of a Tineid moth, *Gelechia gossypiella*), which seems to be identical with the "pink-spotted boll worm" affecting cotton in India. The Japanese beetle (*Adoretus umbrosus tenuimaculatus*) skeletonizes the leaves. A mealy bug (*Pseudococcus filamentosus*) produces considerable injury on young plants and about forming buds and bolls, and the tender foliage and blossoms suffer from the attacks of an aphid. The cotton boll worm (*Heliothis obsoleta*) of the southern United States is found on tobacco and corn in Hawaii, but if cotton planting becomes extensive its spread to this crop may be anticipated.

The determination and study of the life histories, habits, and injuries of these pests will be a feature of the coming year's work.

As in the past, the writer is pleased to record the courtesies received from co-workers in Hawaii and abroad, and would point especially to the aid and advice given by Dr. L. O. Howard, Chief of the Bureau of Entomology of the U. S. Department of Agriculture. The writer would mention here also the kindly suggestions and helpful support received from Mr. Jared G. Smith, Special Agent in Charge of this station.

THE HORN FLY.

(*Haematobia serrata*).

The horn fly was introduced into Hawaii with shipments of cattle from the western coast of the United States to the island of Oahu during 1897. Within a year it had spread to all the other islands. In the ten years that have since elapsed, it has bred uninterruptedly, and the annoyance caused by its blood-sucking habit has been felt during this time by all the thousands of cattle on Hawaiian ranches. The smaller dairy herds have likewise suffered. Horses are bothered to some extent by the fly, especially when near cattle. Recently, Nörgaard has pointed out the complication of sheep-scab and horn fly injury on sheep.* To this complication has been added, later, that of the maggot flies, which in many cases take up the work of destruction in

* Report of the Division of Animal Industry, Rept. Bd. Commrs. Agr. and Forestry, Hawaii, 2 (1905,) pp. 171, 211,212.

connection with, or subsequent to, the injuries caused by the scab mite and horn fly.

While the horn fly in the United States and Canada causes more or less loss to the live stock and dairy industries, it is checked in these countries by two distinct seasons, a cold and wet and a hot and dry season. As warm wet weather is required for the continuous development of the horn fly, it would seem that the Hawaiian Islands offer an especially favorable breeding ground for this pest. The horn fly requires but little rainfall, and finds here an equable temperature, varying but slightly with the seasons, and at no time detrimental to its propagation. Prolonged drought will check it, ordinary dry weather retard it, but climatic conditions which might be called destructive to it rarely occur here. It is, therefore, little wonder that, once introduced here, it required but a short time to spread all over the Territory and to multiply to such an extent as to make Hawaii compare with the worst infested sections of the mainland.

The two lines of control that are offered for the horn fly are, as with all insect pests, preventive and curative measures. Prevention includes the destruction of the larvae in cattle dung by direct measures or by the introduction of natural enemies that will feed upon them. Curative measures include protection of the cattle from the attacks of the fly or the wholesale destruction of the adult flies. All of these methods of control have received serious consideration as evidenced by the many reports dealing with the treatment of cow dung to destroy the breeding place of the larvae, the introduction of natural enemies from one country to another, the spraying of cattle with repellent mixtures and trapping and spraying experiments to destroy the adult fly. These various methods and their application must be considered with reference to Hawaiian conditions. The use of repellents does not appear feasible in Hawaii except in the case of our dairy herds, and even there they should be used only in conjunction with preventive measures for the destruction of the larvae in the dung. Prevention, therefore is the keynote to the control of the horn fly.

The large areas comprising the cattle ranges and the semi-wild condition of the herds give emphasis to the idea that the only hope of permanent relief for beef cattle lies in procuring effective natural enemies. The serious menace that faces cattle raising so long as the horn fly ravages remain unchecked, justifies the continuation of efforts to procure such enemies from abroad, and to establish and encourage promising species already within the Territory. This phase of control work, however, should not deter the stockmen from doing their share toward the suppression of the pest, as natural enemies do not become a factor until they are obtained and established. In other words, while supporting investigations relating to this work, ranchers should not allow the possibility of direct measures of control to pass from their minds.

Great benefit could be derived were it possible to destroy wholesale the adult flies on cattle in the fattening paddocks. It is a well-known fact that cattle in a fattening paddock cannot be finished for market while the flies are bad even when their feed is abundant. It would be highly desirable to submit such cattle to one or two dippings or sprayings, providing such operations would afford perfect rest to the cattle for at least a month or six weeks before going to market. However, it is only where the application of such remedies can be made on a scale promising returns in proportion to the time and labor expended that they can be considered.

The habits of horn flies are such that they never fly any great distance from the cattle or leave them for any length of time. Whether they rest on foliage or grass in any numbers is not known, but it is safe to conclude from the observations made by many investigators and from our own experience that when all of the animals in the pasture are rounded up, nearly all of the adult flies are around the animals, including the cow-ponies. As the flies are very light and as they are easily carried by the wind, to free a pasture from adult flies would require that all animals be rounded up and driven with the wind out of the pasture and then put through the dip or spray and back into the same pasture against the wind. To prevent any of the flies returning with the cattle it might be well to build a funnel-shaped canvas-covered guard at the entrance to the place of treatment and a long brush-covered chute at the exit. Two weeks after the first treatment the operation should be repeated, in order to destroy the horn flies which have since developed. It is a safe conclusion that all of the flies which are left behind and which are not destroyed in the treatment will assemble on or around the horses of the cowboys and annoy them greatly, and if any cowboy returns to the (presumably) clean pastures, thousands of flies will follow.

Still better results might be obtained if the pasture to be freed from flies could be left empty for two to four weeks after the cattle and flies have been removed, but until something definite is known as to what becomes of horn flies which are hatched in the pasture where there are no animals to feed on, how long they can live without food, and what distances they will travel in search of food, nothing certain can be said in regard to the length of time the pasture should be allowed to rest, to completely free it from the flies. From deductions made from observations of other species, it is, however, safe to conclude that the above-mentioned period, two to four weeks, would be sufficient for the great majority of them to disappear.

To attend to the droppings of animals, however small the number or however easy the method, is practically out of the question except on dairy ranches. It has been estimated that perhaps 50 per cent of the developing flies can be found in the dung in the vicinity of watering places, pens, and shady retreats.

The cakes are found in greater numbers and more eggs are probably deposited in them than in those which are dropped over the range. The same applies to cattle yards near dairies or farms where the animals are being held at milking time. Appropriate treatment of the dung in these places would destroy a proportionately large number of larvae.

A still less expensive method of scattering the dung in yards and pens is to allow a number of pigs to run with the cattle. In their efforts to obtain undigested particles of food they will effectively destroy the cakes as breeding places for the fly larvae, at least during the dry season. This is especially noticeable in feed yards on the mainland where hogs sometimes follow cattle, and, to a certain extent, in the algaroba belts of these islands.

That the prevalence of insect pests in the Territory is due, to a great extent, to the almost total absence of insectivorous birds, can not be doubted. The writer has conferred with Prof. H. W. Henshaw in regard to the introduction of birds, particularly those that are destructive to flies. Prof. Henshaw is familiar with the conditions in these islands and offers every encouragement to the hope that desirable birds can be found. The necessity of studying carefully the feeding habits of any bird introduced, before it is liberated, has been pointed out by all who have been consulted, and for this purpose an observational aviary will be established in connection with the Pacific Scientific Institute. The station has arranged to work in coöperation with Mr. W. A. Bryan, President of the Pacific Scientific Institute, in its efforts to secure valuable insectivorous birds.

THE SHEEP-MAGGOT FLY.

(*Calliphora dux*).

The Hawaiian sheep-maggot fly was first collected by the writer on the island of Molokai. It was forwarded to Washington for determination, and Mr. D. W. Coquillett, of the Bureau of Entomology, identified it as the above-named species, which had not hitherto been recorded from the Territory of Hawaii and is here for the first time known as an animal parasite. No reference can be found in the literature of animal parasitism, to a similar case of a practically obscure species, supposedly infesting only dead animal tissue, suddenly adapting itself to living animals with such serious results. The outbreaks that have thus far come to our notice are sufficient to place the species in the front rank of the pests with which stockmen in Hawaii will have to deal, especially in sheep raising.

The fly has probably been in this Territory for a comparatively long time, and, while details have not yet been secured, enough information is at hand to show that sporadic cases of "blown" sheep have occurred in past years without epidemics resulting from them. An understanding of our own species has been

extended by references to similar injury to sheep from different, though related, species in the British Isles and Australia. The problem is far from being solved, and demands extended and detailed study before definite conclusions can be reached.

The fly itself can be recognized as the species with bluish green metallic coloration which breeds wherever decaying flesh is left exposed. On the ranches, where it occurs, it is always attracted in numbers when animals are slaughtered. The fly will "blow," that is, deposit its eggs, on any exposed meat or in any wound, but preferably when the wound has become foul. Its development as a parasite of sheep in this Territory began by the flies blowing the scars from sheep scab which had been irritated to bleeding by the horn fly. The attack of the blow fly, combined with the sheep-scab and horn fly injury, in some instances resulted in the death of the animal; and from the carcasses of the dead sheep innumerable flies developed. From this source the fly became epidemic and began to blow not only the sheep-scab wounds, but also dead wool or wool fouled in any manner, especially on sheep or lambs suffering with scours.

When the eggs are deposited on wool, the resulting maggots, which appear within twenty-four hours, work down through the wool to the body. They do not attempt to penetrate the unbroken skin, as do the screw-worm maggots, but work in a constantly moving, intermingled mass over the surface, causing irritation, which brings about inflammation and ulceration, on the products of which the larvae feed. Later, the wool drops off, leaving a festering ulcer that is constantly being reblown, while masses of eggs are also being deposited in the filthy wool surrounding the sore. Such an infestation, of one week's standing, will contain maggots in all stages of development, as well as unhatched eggs. When the skin is completely destroyed, the maggots penetrate with ease in all directions under the skin, forming fistulas and sinuses, and the animal dies from septicemia or from exhaustion.

As the maggots mature, they drop to the ground and pupate in the soil. The life cycle does not extend over more than three weeks and the larvae or maggots develop in less than ten days.

No remedy has yet been found that in one application will kill the maggots, disinfect the wound, and prevent reinfection. The present treatment is a dual one. All loose and foul wool is removed and destroyed and the wound and surrounding skin are treated with a mixture of chloroform and kerosene oil in the proportion of 1 to 10. This dislodges and kills all the maggots. An application is then made, with a brush, of a mixture of flowers of sulphur and Stockholm tar in equal proportions by measure, to which has been added a small amount of sperm oil (1 quart to 5 gallons of the mixture) to give elasticity to the resulting crust. The wound heals well under the crust, which not only protects it from being reblown, but also from attacks by the horn fly. With the exception of aggravated cases, one treat-

ment is sufficient, but the treated animals must be watched closely, as they are likely to bite off the crust on account of the itching which accompanies the healing process.

By far the most important measure in dealing with an epidemic of maggot flies is to locate the affected animals, and this is, to say the least, extremely difficult when the animals are on the open range or in large pastures, and with sheep which are not accustomed to being herded it is impossible to get near enough to them without rounding up the entire lot and examining them in a corral. On the open range or in pastures containing perhaps 10,000 acres, only the worst cases can be seen, when they lag behind the herd from weakness. Such animals may just as well be killed and buried on the spot, in which case care should be taken to bury them deep enough to exclude the possibility of newly hatched maggots working down to them, as the stench which rises to the surface from a carcass in a shallow grave will cause numerous flies to deposit their eggs on top of it. The writer has seen such a grave, from which the egg masses could be scooped up in double handfuls. This fully illustrates the necessity for disposing effectively of all dead animals, especially during an epidemic.

Equal care must be taken to destroy all eggs and maggots in pens where affected animals are being tagged or treated. We have seen the ground in such a pen completely covered with newly hatched flies, sitting so close together as to lend a greenish sheen to the surface. Two or three weeks before this observation was made, a number of sheep had been treated there for maggots. The affected animals should be treated and sheared on a piece of canvas or a wagon-sheet and the rubbish collected and burned.

BEE KEEPING.

The year has been marked by a decided impetus to the bee-keeping industry. The last estimate of the annual crop was 600 tons. This season's crop will amount to nearly 1,000 tons. Two reasons can be assigned for this increase, (1) a normal flow from the algaroba, and (2) the extension of the industry, i. e., increase of the number of colonies and establishment of new locations. The number of colonies at present in the Territory is not far below 20,000. Two companies have begun operations on the Island of Hawaii (the largest island of the group) and one concern at least on account of the many desirable locations available is in a position to increase rapidly. On the Island of Kauai the greatest extension of the industry has occurred and two corporations are well established. The Island of Oahu is practically the only island where the available territory is occupied, with the possible exception of the lee side and west end of the Island of Molokai. One corporation is now well established on the Island of Maui and an increase has been made on

this island with the opportunity for still further increase. The honey and wax crop of the islands is worth in round numbers $100,000, and the next few years will see the production increased by at least one-half.

A survey of the available bee plants, apiaries, and locations for apiaries, which is under way, has been completed for the Island of Molokai. Several trees and plants of value as bee pasturage have been introduced, and some of these are now established. In regard to the introduction of plants, the general policy has been that only plants possessing a dual value will be considered, that is, plants which not only produce nectar but are of value as forage or timber. This will obviate the danger of establishing in the Territory any plant which might become noxious. The lantana is a great object lesson in this respect. The following is a list of the plants that produce nectar in Hawaii:

THE SOURCE OF HONEY IN THE HAWAIIAN ISLANDS.

FOREST TREES.

Algaroba, keawe (*Prosopis juliflora*). This tree is the most abundant and important nectar-producing plant in the Hawaiian Islands. The principal apiaries are situated along the leeward coasts in the shelter of the algaroba forests. The honey is of a high grade.

Texas mesquite (*Prosopis glandulosa*) was found growing in the dooryard of Mr. C. C. Conradt, Pukoo, Island of Molokai. Seedlings are being propagated at the station. This tree was introduced from Texas by Mr. Conradt several years ago.

Ohia lehua (*Metrosideros polymorpha*) produces a particularly high grade of honey. Locations for apiaries as a rule are somewhat inaccessible. One location on the Island of Molokai is within the ohia lehua belt.

Various species of acacia (black wattle, koa, etc.) occur in mountainous districts.

Various species of eucalyptus are found in mountainous districts.

Wiliwili (*Erythrina monosperma*) occurs in gulches on Molokai and Oahu.

Rose-apple (*Eugenia jambosa*) and Mamani (*Sophora chrysophylla*) are found in higher forest belts.

Catalpa (*Catalpa speciosa* and *C. bignonioides*) was introduced by Mr. Jared G. Smith, April, 1902, from the Missouri Botanical Gardens. The seeds were distributed to the Makawao district and Puunene on Maui; to the Moanalua Gardens on Oahu; to Makaweli on Kauai, and to Hamakua and Kohala districts on Hawaii. No reports are on file at this station as to the results of this introduction.

Logwood (*Haematoxylon campechianum*) is found in dooryards. Two trees are growing in the grounds of Oahu College

and one in the grounds of Lunalilo Home, Honolulu. Seedlings are now being propagated at the station. The honey produced by bees from this tree is reported to be the finest table honey in the world. The propagation and distribution of the logwood throughout the Territory would be of great value to bee keepers, and the wood furnishes the logwood dye of commerce.

The black mangrove of Florida was introduced by Mr. Jared G. Smith from Southern Florida, for the purpose of holding the mud flats along the coast of Molokai near Kaunakakai from washing. The introduction was made several years ago and the trees are now well established at the above mentioned place. The tree is a valuable honey plant. The station has also secured the Philippine mangrove, a tree suitable for similar locations but possessing greater value as a timber tree.

FRUIT TREES.

Various citrus species (orange, lemon and lime), avocado (*Persea gratissima*), banana (*Musa* spp.), guava (*Psidium* spp.), loquat (*Eriobotrya japonica*), and tamarind (*Tamarindus indica*).

PASTURE PLANTS.

California bur clover (*Medicago denticulata*) was introduced on Maui in 1882 by Mr. C. R. Blacow, and is now found generally on the ranches of the islands.

Carpet grass (*Lippia repens*) is growing on grounds of the station.

Alfilaria or filaree (*Erodium cicutarium* and *E. moschatum*) seeds were introduced in California hay, and has become established on upland pastures on Hawaii and Molokai.

White clover (*Trifolium repens*) is found on Haleakala and Makawao pastures, Maui.

CROP PLANTS.

Sisal (*Agave sisalana*).

Various species of cucurbits (melons, squashes, pumpkins, cucumbers, etc.).

FORAGE PLANTS.

Alfalfa, several varieties.

Lupine, blue and yellow, is occasionally used as green-manure plant on sugar plantations.

Tangier pea (*Lathyrus tingitanus*) is growing at Haiku, Maui.

Sanfoin (*Onobrychis sativa*) is a forage plant introduced by Jared G. Smith in 1904. The seed was distributed to ranches.

ORNAMENTAL PLANTS.

Palms, particularly the royal and cocoanut.

Poppy, a horticultural form of *Romneya coulteri* is found in gardens in Honolulu.

Chinese ink-berry (*Cestrum diurnum*), *Thevetia neriifolia* and vines (*Ipomoea* spp.).

WEEDS.

Lantana, two species.

California sages (*Salvia*) were introduced by Hawaiian Bee Keepers' Association in 1907, but are not as yet established. They are suitable for waste, arid lands, are the most important honey plant in California and are also valuable as forage plants.

Ilima (*Sida* spp.), oi (*Verbena bonariensis*), pili grass (*Heteropogon contortus*), Spanish needle or lauki (*Bidens pilosa*), puakala (*Argemone mexicana*), alii (*Dodonaea viscosa spathulata*), and hila hila (undetermined). Other weeds are *Waltheria americana, Ipomoea pes-caprae* (vine along seacoasts), and *Malvastrum tricuspidatum.*

INSECT HONEYDEW.

The most important source of honey in the Hawaiian Islands, aside from the amount elaborated from the nectar of the flowers of algaroba, is honeydew derived from the secretion deposited on the leaves of sugar cane by the sugar cane leaf hopper (*Perkinsiella saccharicida*). Insect honeydew is derived, to a limited extent, also from the secretions of the sugar cane aphis (*Aphis sacchari*).

Further, in Hawaii, as in other tropical countries, plant lice, scale insects, and related families are abundant, and some insect honeydew is to be found on plants in almost any locality.

PLANT HONEYDEW.

While no great amount of this product is gathered and stored by honeybees in Hawaii, bees have been observed locally collecting the plant honeydew secreted by the extra floral nectaries on the leaves of hau trees (*Paritium tiliaceum*). The planting of cotton on a large scale will mean an increase in plant honeydew pasturage, since similar glands are found on the bracts of the bolls and the midrib of the leaves of the cotton plant.

A bulletin on Hawaiian Honey was published during the year. This bulletin is available for distribution and presents the character and source of the honeys of the islands in detail.

An event of great importance to the bee-keeping interests in Hawaii was an extended visit to the islands by Dr. E. F. Phil-

lips, in charge of apiculture in the Bureau of Entomology. Dr. Phillips arrived in the latter part of February, 1908, and remained until April 1, visiting during this time all the principal apiaries on the islands of Oahu, Kauai, Molokai, Maui and Hawaii. The Hawaiian Bee Keepers' Association has taken an active part in the introduction of bee plants and in securing legislation pertaining to the importation and inspection of honeybees and honey.

PINEAPPLE INSECTS.

In 1904 the writer published a report on the pineapple scale (*Diaspis bromeliae*). With the great increase in the acreage devoted to pineapple culture, the mealy-bug (*Pseudococcus citri*) has become equally as serious as the scale if not more so. The scale is primarily leaf-feeding, while the mealy-bug infests the roots, the basal portions of the leaves, the center of the plant, and is particularly abundant at the base of the fruit. Aside from the injury to the plant, the mealy-bug injures the fruit directly by its feeding and indirectly by acting as an agent in the spread of the pineapple rot. The resulting injury blemishes the fruit, making it unfit for the fresh-fruit trade, and greatly impairs its keeping qualities during shipment.

Because of the large area of land now in pineapples it is important to control these species, both from the standpoint of increasing the production and from that of producing fresh fruit for shipment. The modern market will not accept inferior or infested fruit. The Hawaiian product is a superior fruit and the growers have undertaken vigorous measures to suppress insect pests.

During the last season it has been demonstrated that the scale and mealy-bug can be controlled in the field and that clean shipments of fruit are possible by proper methods of fumigation. It is sufficient to say that the fruit has passed inspection under the rigid horticultural quarantine law in operation at the port of San Francisco.

Trial fumigation of plants before setting them in the field indicates that plants will not stand as large a dosage of cyanid gas as fruit for shipment. In the case of fruit for shipment it is possible to use a dosage that will kill all forms of both the pineapple scale and the pineapple mealy-bug without injuring the fruit. Tests demonstrate that the plants are more susceptible to injury, and until the point of safety to which the dose can be increased is determined, the following dosage for the fumigation of plants is recommended: For every 100 cubic feet of air space use 1 ounce by weight of potassium cyanid, 2 fluid ounces of sulphuric acid, and 4 fluid ounces of water. The time required is one and one-half hours. A relatively smaller dose, with longer exposure, is less injurious than a larger dose and shorter exposure. Economy of labor can be obtained by increasing the capacity of the fumigation outfit in proportion to the length of

time. With the above dose nearly all of the active forms are killed. The individuals developing from the immature forms must be treated later in the field.

For field treatment, an emulsion of kerosene is recommended for the scale, and tobacco dust for the mealy-bug. The kerosene emulsion is described in Press Bulletin No. 10. The tobacco-dust treatment consists in applying a small handful in the center of the plant, care being taken not to use the dust when the bud is forming or while the plant is in flower. Tobacco dust has been placed on the market in Honolulu for less than $45.00 per ton.

For fruit for shipment a larger dosage may be used, and 1½ ounces of potassium cyanid is recommended to every 100 cubic feet of air space, the proportion and time being the same as given for fumigating plants.

Fumigation work is being successfully done under canvas treated with oil or paint and in special air-tight rooms. The growers have the work well in hand and the insects affecting pineapples in Hawaii present no serious obstacles in the production and marketing of the fruit.

Acknowledgment is made of the helpful coöperation and suggestions of Mr. E. M. Ehrhorn, horticultural inspector at the port of San Francisco, in the work of determining the proper dosage for the fumigation of fruit for shipment.

MOSQUITOES.

The investigations relating to mosquitoes have been brought to a close. The important facts concerning the species of mosquitoes found in Hawaii, their breeding places and habits, and measures for their suppression, have been worked out and the information given to the public in bulletin form and in the reports of the station. The control of mosquitoes has been assumed by the Territorial Board of Health. The inspectors of the Board are doing very efficient work, in consideration of the fact that no funds for the work are available and consequently no addition to the force possible.

On August 3, 1906, regulations were adopted for mosquito prevention and abatement and made a part of the rules and regulations of the Board of Health of the Territory of Hawaii.

A REVISED LIST OF THE INJURIOUS INSECTS OF HAWAII.*

The list of injurious insects of Hawaii was begun in the report of the entomologist for the fiscal year 1904. The annual reports of the station have appeared in widely separated publications of the Department and some of the early reports are not now available. On this account and for the further reason that many additional determinations have been made and that some corrections are necessary it is deemed advisable to give herewith the complete list with references to the former reports. Additions to the list are given to bring the report down to date.

CROPS.

SUGAR.

The sugar-cane leafhopper (*Perkinsiella saccharicida*).[a]
The sugar-cane borer (*Sphenophorus obscurus*).[a]
The sugar-cane leaf-roller (*Omiodes accepta*).[a]
The sugar-cane mealy-bug (*Pseudococcus calceolariae*).[a]
The sugar-cane aphis (*Aphis sacchari*).[c]
Mole cricket (*Gryllotalpa africana*).[a]
Cockroach (*Eleutheroda dytiscoides*).[a]
Fuller's rose beetle (*Aramigus fulleri*).[a]
Longhorned grasshopper (*Xiphidium varipenne*).[c]

RICE.

The rice weevil (*Calandra oryza*).[c]
The Angoumois grain moth (*Sitotroga cerealella*).[d]
Mole cricket (*Gryllotalpa africana*).[c]
Longhorned grasshopper (*Xiphidium varipenne*).[c]
Shorthorned grasshopper (*Oxya velox*).[c]
The rust-red flour-beetle (*Tribolium ferrugincum*).[c]
The cadelle (*Tenebrioides mauritanica*).[c]
A beetle (*Rhizopertha pusilla*).[d]

COFFEE.

Scale insect (*Pulvinaria psidii*).[a]
Leafhopper (*Siphanta acuta*).[a]
Aphid (undetermined).[a]

---

*The letters after the names in the list refer to former reports as follows:

[a] Ann. Rept. Hawaii Expt. Sta. 1904, U. S. Dept. Agr., Office Expt. Sta. Rpt. 1904, Washington, 1905, pp. 372-379.

[b] Report on Arigultural Investigations in Hawaii 1905., U. S. Dept. Agri. Office Exp. Stas. Bul. 170 Washington 1906, pp. 38-59.

[c] Ann. Rpt, Hawaii Exp. Sta. 1906, Washington, 1907, pp 18-32.

[d] Ann. Rpt. Hawaii Exp. Sta. 1907, Washington, 1908, pp. 25-51.

[e] Rpt. Governor Ter. of Hawaii, 1902, p. 35.

TARO.

Mole cricket (*Gryllotalpa africana*).[b]
Aphid (undetermined.)[b]

SISAL.

A weevil (*Pseudolus longulus*).[b]
Mealy-bug (*Pseudococcus* sp. undetermined).[b]
The black scale (*Saissetia oleae*).[b]

TOBACCO.

Tobacco leaf-miner (*Phthorimaea operculella*).[a]
Tobacco flea-beetle (*Epitrix parvula*).[a]
Tobacco hornworm (*Phlegethontius quinquemaculata*).[b]
Cigarette beetle (*Lasioderma serricorne*).[b]
Black cutworm (*Agrotis ypsilon*).[a]
Bollworm (*Heliothis obsoleta*).[a]
Japanese beetle (*Adoretus umbrosus tenuimaculatus*).

COTTON.

Bollworm (*Heliothis obsoleta*). This insect is the widely known bollworm of cotton of the southern United States. The writer observed its work on the young buds of tobacco in 1905, and in restricted areas its work was serious. It is periodically injurious to the ears of corn. The insect has not been observed on cotton nor is the species at all common. Since many of the food plants of the worm are common it would seem that the insect is held in check by some natural factor, probably tachinid flies. It is, however, an insect whose presence in the cotton fields it is well to anticipate.

Japanese beetle (*Adoretus umbrosus tenuimaculatus*). The Japanese beetle has been observed to skeletonize the leaves of the cotton plant in many of the plantings of cotton that have been made on a small scale in isolated places. The behavior of the beetle in fields of considerable area can not be predicted, but as it is a leaf feeder, its injury in the first place will not be as serious as that of forms attacking the boll; in the second place, it can be controlled by spraying with an arsenical poison. It is of interest to note that the Japanese beetle showed a decided preference for the Chinese variety of cotton—in comparison with the Caravonica—in the plantings made at the station during the year.

Small bollworm (*Gelechia gossypiella*). This species is noted by Dr. R. C. L. Perkins in 1902 as "Gelechiid (undetermined) attacking cotton bolls"[c] and recorded by Lord Walsingham under the above determination from Hawaii in Fauna Hawaiiensis[b] with the description and extended notes on the occurrence

of the species in India and Japan. The moth was bred by the writer from infested cotton bolls received from Holualoa, Kona, Island of Hawaii, in 1905, and is common about Honolulu. A detailed study has been begun of the life-history of this moth and this with the feeding habits of the worm and possible means of suppression on a field basis will form the important part of the investigations to be undertaken by the assistant entomologist during the year.

A weevil (*Araeocerus fasciculatus*). This weevil was bred from cotton bolls received from Hookena, South Kona, Island of Hawaii, in December, 1905. Determined by Mr. E. A. Schwarz of the Bureau of Entomology.

Mealy-bug (*Pseudococcus filamentosus*). Very abundant at times on the young stems and bolls. Fed upon to a great extent by the ladybird beetle (*Cryptolaemus montrouzieri*).

Cotton aphis (*Aphis gossypii*). Determined by Mr. Th. Pergande of the Bureau of Entomology. Fed upon by larva of syrphus fly (*Xanthogramma grandicornis*) and predaceous plant-bug (*Zelus peregrinum*).

CASSAVA.

A snout-beetle (*Pseudolus longulus*).[b]
A longhorned beetle (*Lagocheirus araneiformis*).[b]

SWEET POTATO.

Sweet-potato weevil (*Cylas formicarius*).[d]
Sweet-potato sphinx (*Phlegethontius convolvuli*).[d]
Sweet-potato vine borer (*Omphisa anastomosalis*).[d]
A root maggot (*Pegomya fusciceps*).[d]

CORN.

Corn leaf hopper (*Dicranotropis maidis*).[a]
"Green fly" of corn (undetermined species of aphidid.)[a]
Cutworms (several undetermined species, among them *Agrotis ypsilon*).[a]

CABBAGE.

Cabbage aphis (undetermined, probably *Aphis brassicae*).[a] An internal parasite (*Lysiphlebus testaceipes*) has been bred from this aphis. It forms an important natural check to the aphis here.

A leaf-miner (*Plutella maculipennis*).[b] Parasitized by *Campoletis* (*Limneria*) *tibiator*.
Root maggot (*Pegomya fusciceps*).[d]
The cabbage butterfly (*Pontia rapae*).[a]
Cutworms (undetermined).[a]

MELONS.

The melon fly (*Dacus cucurbitae*)[a], illus. art.[d] It is believed that at the present price of melons it would pay to grow muskmelons at least, under cover, fertilizing the flowers by a colony of bees.

Aphidid (undetermined). Very abundant on young vines.

Stem borer (*Apomecyna pertigera*) larva of a Cerambycid. Taken in numbers from stems of watermelons at Makaha, island of Oahu. Determined by Mr. E. A. Schwarz of the Bureau of Entomology.

PINEAPPLE.

Pineapple scale (*Diaspis bromeliae*).[a]

Common mealy-bug (*Pseudococcus citri*).[d]

The pomace fly (*Drosophila ampelophila*).[d]

Red spider (*Stigmaeus floridanus*), Banks. Taken from pineapple on station grounds during the year.

CITRUS.

Purple scale (*Lepidosaphes beckii*).[a b]

Fluted scale (*Icerya purchasi*).[a]

Orange aphis (*Myzus citricidus*).[a c]

Scale (*Parlatoria ziziphus*).[d]

Leafhopper (*Siphanta acuta*).[a]

Common mealy-bug (*Pseudococcus citri*).[d]

Bark beetle (*Stephanoderes* sp.)[b]

Florida red scale (*Chrysomphalus aonidum*).[c]

Scale (*Pulvinaria psidii*).[c]

Mealy-bug (*Pseudococcus filamentosus*).[c]

Scale (*Coccus viridis*).[c]

Fuller's rose beetle (*Aramigus fulleri*). Injurious to limes on the island of Molokai during the summer of 1907.

Scale (*Coccus punctuliferus*). Collected from lime at Makaha, island of Oahu. Determined by Mr. Sanders of the Bureau of Entomology.

Cockroach (*Eleutheroda dytiscoides*). Determined by Mr. Caudell of the Bureau of Entomology. Received from Napoopoo, Kona, island of Hawaii. Reported as injurious to lime trees by girdling the branches.

MANGO.

The mango weevil (*Cryptorhynchus mangiferae*).[b]

Torpedo bug (*Siphanta acuta*).[a]

Scale (*Phenacaspis eugeniae*).[b]

The mango scale (*Coccus mangiferae*).[c]

Florida red scale (*Chrysomphalus aonidum*).[c]

Scale (*Trionymus americanus*).[d]

Thrips.[d] Mr. Th. Pergande of the Bureau of Entomology identified the thrips on the mango as *Heliothrips* sp, and says under date of March 3, 1908, that the species is apparently new.

Scale (*Pulvinaria mammeae*). Found also on orange, coffee and ferns. Originally described from Hawaii on the mammee apple (*Mammea americana*). Determined by Mr. J. G. Sanders of the Bureau of Entomology.

BANANA.

The sugar-cane borer (*Sphenophorus obcurus*).[a]
A borer (*Calandra remota*).[a]
The banana leaf-roller (*Omiodes meyricki*).[a d]
Florida red scale (*Chrysomphalus aonidum*).[b]
Scale (*Phenacaspis eugeniae*).[b]
Scale (*Saissetia nigra*).[c]

AVOCADO.

Avocado mealy-bug (*Pseudococcus nipae*).[a]
Scale (*Fiorinia fioriniae*).[a]
Scale (*Phenacaspis eugeniae*).[b]
Bark beetle (*Xyleborus immaturus*).[b]

FIG.

Avocado mealy bug (*Pseudococcus nipae*).[a]

Scale (*Saissetia nigra*). Taken from fig in Moanalua Gardens, Honolulu.

GRAPE.

Japanese beetle (*Adoretus umbrosus tenuimaculatus*).[a c]
Avocado mealy bug (*Pseudococcus nipae*).[a c]
Fuller's rose beetle (*Aramigus fulleri*).[c]
Mealy bug (*Pseudococcus filamentosus*).[c]
Larva of moth (*undetermined*).[c]

APPLE.

Japanese beetle (*Adoretus umbrosus tenuimaculatus*).[d]
Scale (*Pseudaonidia clavigera*).[d]

PEACH.

Fuller's rose beetle (*Aramigus fulleri*). Observed during the year in very destructive numbers on peach on the island of Molokai.

Peach scale (*Aulacaspis pentagona*).[a] Bark beetle, probably an undescribed species. Collected in Nuuanu Valley, Honolulu.

GUAVA.

Avocado mealy-bug (*Pseudococcus nipae*).[a]

Fuller's rose beetle (*Aramigus fulleri*). Feeding to great extent on guava on the islands of Hawaii and Molokai.

MULBERRY.

Avocado mealy-bug (*Pseudococcus nipae*).[c]
Mealy-bug (*Pseudococcus filamentosus*).[c]
Scale (*Saissetia* sp., undetermined).[c]

STRAWBERRY.

A ground beetle (*Ompatrum serratum*).[a]
Japanese beetle (*Adoretus umbrosus tenuimaculatus*. The Japanese beetle is the principal insect injurious to strawberries in Hawaii. The Japanese gardeners control the pest by picking.

SOUR-SOP.

Avocado mealy-bug (*Pseudococcus nipae*).[b]
Scale (*Coccus longulus*).[b]

COCOANUT.

Palm leaf-roller (*Omiodes blackburni*)[d].
Sugar-cane borer (*Sphenophorus obscurus*).[d]
Florida red scale (*Chrysomphalus aonidum*).[d]

ORNAMENTAL PLANTS.

HIBISCUS.

Mealy-bug (*Pseudococcus filamentosus*).[b]
Leaf caterpillar (*Cosmophila sabulifera*).[d]

ROSES.

Japanese beetle (*Adoretus umbrosus tenuimaculatus*).[a]
Rose aphis (*Macrosiphum rosae*).[d]
Rose scale (*Aulacaspis rosae*).[a]
Fuller's rose beetle (*Aramigus fulleri*).[a]

PALMS.

Sugar-cane borer (*Sphenophorus obscurus*).[a]
Hemispherical scale (*Saissetia hemisphaerica*).[b]
Mealy-bug (*Pseudococcus pseudonipae*).[b]
Scale (*Chrysomphalus dictyospermi*).[b]
Florida red scale (*Chrysomphalus aonidum*).[c]

PEPPER TREE.

Scale (*Saissetia nigra*).[d]
Scale (*Aspidiotus lataniae*).[d]

BAMBOO.

Scale (*Asterolecanium miliaris*).[d]

CROTON.

Scale (*Lepidosaphes pallida*)[b].

IPOMOEA.

Scale (*Coccus hesperidum*). Parasitized by *Coccophagus immaculatus*).[b]

Sweet potato sphinx (*Phlegethontius convolouli* Linn). Collected from vines at the station.

OLEANDER.

Scale insect (*Phenacaspis eugeniae*).[c]

ASPARAGUS.

(*Asparagus sprengeri.*)

Avocado mealy-bug (*Pseudococcus nipae*). Collected during the year on the station grounds.

Scale (*Hemichionaspis minor*). Collected during the year on the station grounds. Determined by Mr. J. M. Sanders, of the Bureau of Entomology.

FOREST TREES

ALGAROBA.

(*Prosopis juliflora.*)

Longhorned beetles (*Cyllene crinicornis* and *Microcantha nutans*).[b]

Large powder beetle (*Bostrichus migrator*).[b]

Small powder beetle (*Sinoxylon conigerum*).[b]

The bean weevil (*Bruchus obtectus*).[b]

Scale insect (*Asterolecanium pustulans*).[d]

BLACK WATTLE.

(*Acacia decurrens.*)

Longhorned beetles (*Cyllene crinicornis, Xystrocera globosa, Ceresium simplex,* and *Sotenus setiger*).[b]

Weevil (*Bruchus* sp.).[b]

Wireworm (*Chalcolepidius erythroloma*).[b] Probably injurious to roots.

Barkbeetle (*Stephanoderes sp.*).[b]

Leafhopper (*Siphanta acuta*).[b]

Fluted scale (*Icerya purchasi*).[b]

Caterpillar of tineid moth (undetermined).[b] Beneath bark.

CEARA RUBBER.

Scale insects (*Saissetia nigra, Saissetia oleae,* and *Aspidiotus cyanophylli*).[c d]

Mealy-bug (*Pseudococcus* sp., undetermined).[c]

Barkbeetle (*Xyleborus affinis*).[d]

Snout-beetle (*Pseudolus longulus*).[d]

Wireworm (undetermined Elaterid).[d]

OHIA LEHUA.

(*Metrosideros polymorpha.*)

Fuller's rose beetle (*Aramigus fulleri*). This beetle is a very serious enemy of Ohia in certain districts on the island of Hawaii. Trees were observed in the Kohala mountains that were completely defoliated.

Termite (*Calotermes castaneus*). Taken from living trees in the Kohala mountains, island of Hawaii.

WILD GUAVA.

Barkbeetle (*Xyleborus affinis*).[d]

Scale insect (*Aspidiotus lataniae*).[d]

CATTLE.

Hornfly (*Haematobia serrata*).[a] [d]

Warble flies (*Hypoderma bovis* and *H. lineata*).[d]

SHEEP.

Sheep-maggot fly (*Calliphora dux*).[d]

Bluebottle flies (*Lucilia sericata* and *L. caesar*).[d]

Flesh flies (*Sarcophaga barbata* and *S. pallinervis*).[d]

Sheep head-maggot fly (*Oestrus ovis*).[d] This sheep head-maggot was taken from the head of a lamb on Molokai during the year and adult flies reared from the larvae. As previously stated, the species is recorded by Grimshaw from the island of Kauai in 1901. Its presence on the island of Molokai indicates that this persistent pest to sheep is established in the islands.

Horn fly (*Haematobia serrata*).[d]

HORSES.

Stable fiy (*Stomoxys calcitrans*).[d]

Horse botflies (*Gastrophilus equi* and *G. nasalis*).[d]

"Night" mosquito (*Culex cubensis*).[d]

POULTRY.

The turkey louse (*Goniodes stylifer*). Collected on the island of Molokai during the year.

The chicken louse (undetermined).[d]

The chicken mite (undetermined).[d]

The "night" mosquito (*Culex cubensis*).[d]

HOGS.

The hog louse (*Haematopinus urius*). Received from Kamehameha School, Honolulu, during the year. Collected by F. G. Krauss.

DOGS.

The dog flea (*Ctenocephalus canis*).[d]

The dog tick (*Rhipicephalus sanguineus*).[d]

The "night" mosquito (*Culex cubensis*).[d] The mosquitoes—and especially the "night" mosquito—annoy all domestic animals, this annoyance being particularly noticeable in the case of horses, young poultry and dogs. It is believed, further, that this species is the transmitting agent of the disease of dogs known as "heartworm."

HOUSEHOLD INSECTS.

Mosquitoes (*Culex cubensis, Stegomyia calopus* (yellow fever mosquito), and *S. scutellaris*).[a]

Cockroaches (*Periplaneta americana* and *P. australasiae*).[a]

The typhoid or house fly (*Musca domestica*).[a]

Ants. Several species, undetermined, among them the cosmopolitan red ant.

Termite (*Calotermes marginipennis*).[a]

Bedbug (*Cimex lectularius*).

The dog flea (*Ctenocephalus canis*). (See under Live Stock).

Silverfish (*Lepisma* sp., undetermined).[a]

Carpenter bee (*Xylocopa aeneipennis*).[a]

Mud dauber (*Pelopoeus cementarius*).[a]

Clothes moth, undetermined.[a]

STORED PRODUCTS.

Rice weevil, (*Calandra oryza*).[a]

Cigarette beetle (*Lasioderma serricorne*).[a b]

Bean weevil (*Bruchus obtectus*).[a]

Rust-red flour beetle (*Tribolium ferrugineum*).[a]

Angoumois grain moth (*Sitotroga cerealella*). Common in stored rice.

Ham and cheese maggot (*Piophila casei*).[d]

Cadelle (*Tenebrioides mauritanica*).[d]

Weevil (*Calandra linearis*).[d]

Bamboo beetle (*Dinoderus minutus*).[a]

Bone-meal beetle (*Dermestes cadaverinus*).[b]

Beetles (*Silvanus mercator* and *Araecerus fasciculatus*).[d]

Beetle (*Lophocateres pusilla*). Bred from rolled barley during the year.

Book louse (*Troctes divinatorius*). Common pest of dried specimens in museum collections, books, and taken during the year from rice flour.

ACCESSIONS TO ENTOMOLOGICAL LIBRARY RELATING TO HAWAIIAN ENTOMOLOGY.

(Continued from Report of the Entomologist, Annual Report of the Hawaii Agricultural Experiment Station for 1907, pp. 48-51.)

ALDRICH, J. M. A catalogue of North American Diptera. Smithsonian Misc. Collec. No. 1444, p. 1. (Washington, 1905).

BOARD OF COMMISSIONERS OF AGRICULTURE AND FORESTRY. Laws and regulations pertaining to the importation and inspection of honey bees and honey into the Territory of Hawaii. Bd. Comrs. Agr. and Forestry, Hawaii, Gen. Circ. 3. (Oct. 8, 1908).

BROWNE, C. A. Chemical analysis and composition of American honey. U. S. Dept. Agr., Bureau of Chemistry, Bul. 110, 1908.

BURGESSS, A. F., and HOWARD, L. O. The laws in force against injurious insects and foul brood in the United States. U. S. Dept. of Agr., Bureau of Entomology. Bul. 61, 1906.

———. Requirements to be complied with by nurserymen or others who make interstate shipments of nursery stock. U. S. Dept. Agr., Bureau of Entomology, Cir. 75, 1906, p. 2. (Revised, 1908).

CRAW, ALEXANDER. Report of the superintendent of entomology. Hawaiian Forester and Agr. Vol. 4, 1907, No. 2, pp. 343, 344.

———. Report of the superintendent of entomology. Rpt. Bd. Comrs. Agr. and Forestry, Hawaii, 4 (1907), pp. 79-84, pl. 1. (Honolulu, 1908).

FROGGATT, W. W. Australian insects. Sydney: Wm. Brooks & Co., 1907, pp. 28, 78, 79, 82, 211, 290, 346, 361.

GATES, BURTON N. Bee diseases in Massachusetts. U. S. Dept. Agr., Bureau of Entomology, Bul. 75, pt. 3, 1908, p. 23.

GIFFARD, W. M. Presidential address. Proc. Hawaiian Ent. Soc., 1 (1907), pt. 5, p. 176 (April, 1908).

HOLLAND, W. J. The moth book. New York: Doubleday, Page & Co., 1903, p. 43.

HOWARD, L. A. A brief account of the rise and present condition of official economic entomology. U. S. Dept. Agr., Division of Entomology, Insect Life, vol. 7, No. 2, 1894, pp. 79, 98.

——— and BURGESS, A. F. The laws in force against injurious insects and foul brood in the United States. U. S. Dept. Agr., Bureau of Entomology, Bul. 61, 1906.

———. The recent progress and present condition of economic entomology. Science, n. ser., 26 (1907), No. 675, pp. 770, 771, 779.

JARVIS, J. J. Scenes and scenery in the Sandwich Islands. 1837-42. pp. 105-112, 164-169, 223-224.

KELLOGG, V. L. American insects. New York: Holt & Co., 1905, p. 112.

KIRKALDY, G. W. A note on the immigration of Hemiptera into Oceanic Islands. Proc. Hawaiian Ent. Soc., 1 (1907), pt. 5, p. 172. (April, 1908).

———. A bibliographical note on the hemipterous family Aleyrodidae. Proc. Hawaiian Ent. Soc., 1 (1907), pt. 5, p. 185. (April, 1908).

———. A list of the described Hemiptera (excluding Aleyrodidae and Coccidae) of the Hawaiian Islands. Proc. Hawaiian Ent. Soc., 1 (1907), pt. 5, p. 186. (April, 1908).

———. A brief note on three (two new) California Fulgoroid Hemiptera. Proc. Hawaiian Ent. Soc., 2 (1908), No. 1, p. 22.

KOTINSKY, JACOB. Insects affecting rubber plants. Hawaiian Forester and Agr., 4 (1907), No. 10. pp. 304-308.

———. Reports of assistant entomologist. Hawaiian Forester and Agr., 5 (1908), Nos. 4, pp. 90-91, 6, pp. 118-124, 7, pp. 146-149, 8, pp 181-183, 9, pp 203-207

———. Some Coccidae from Singapore collected by F. Muir. Proc. Hawaiian Ent. Soc., 1 (1907), pt. 5, p. 167. (April, 1908).

———. History and present status of *Orthezia insignis*. Proc. Hawaiian Ent. Soc., 2 (1908), No. 1, p. 11.

———. Biography of Alexander Craw. Proc. Hawaiian Ent. Soc., 2 (1908), No. 1, p. 24.

———. Introduction, breeding, and distribution of beneficial insects. Appendix to Report of superintendent of entomology. Rpt. Bd. Comrs. Agr. and Forestry, Hawaii, 4 (1907), pp. 85-89. (Honolulu, 1908).

MUIR, F. Notes on the sugar-cane hoppers and borers in the Malay States and Java. Hawaiian Sugar Planters' Expt. Sta., Div. Ent. Circ. 2, pp. 13. (Oct. 16, 1907).

———. Entomological work in Borneo. Hawaiian Sugar Planters' Expt. Sta., Div. Ent. Circ. 4. pp. 12. (Feb. 19, 1908).

———. Report on the search for the sugar-cane borer in the Malay Archipelago. Hawaiian Sugar Planters' Expt. Sta., Div. Ent. Circ. 6, pp. 9. (May 12, 1908).

———. On the stridulating organ of a Sphingid from Larat. Proc. Hawaiian Ent. Soc., 2 (1908), No. 1, p. 12.

NÖRGAARD, V. A., and VAN DINE, D. L. Insects affecting live stock in Hawaii. Proc. Hawaiian Live-Stock Breeders' Assoc., 5 (1907), pp. 19-70. 1908.

PERKINS, R. C. L. *Callithmysus koebelei* n. sp. Proc. Hawaiian Ent. Soc., 1 (1907), pt. 5, p. 210. (April, 1908).

———. Notes on Hawaiian insects. Proc. Hawaiian Ent. Soc., 2 (1908), No. 1, p. 3.

———. Synonymy of Hawaiian Cynipidae. Proc. Hawaiian Ent. Soc., 2 (1908), No. 1, p. 10.

———. Some remarkable Australian Hymenoptera. Proc. Hawaiian Ent. Soc., 2 (1908), No. 1, p. 27.

SWEZEY, O. H. Sugar-cane leaf roller and its parasites. Hawaiian Planters' Mon., 26 (1907), No. 11, pp. 441-445.

———. Some experiments in breeding *Spodoptera mauritia* Boisd. for color variation. Proc. Hawaiian Ent. Soc., 1 (1907), pt. 5, p. 166. (April, 1908).

———. Nymph of *Dictyophorodelphax mirabilis*. Proc. Hawaiian Ent. Soc., 2 (1908), No. 1, p. 2.

———. Life history of *Caradrina reclusa*. Proc. Hawaiian Ent. Soc., 2 (1908), No. 1, p. 3.

———. Observations on the life history of *Chaetogaedia monticola*. Proc. Hawaiian Ent. Soc., 2 (1908), No. 1, p. 7.

———. The younger stages of *Nesodryas freycinetiae*. Proc. Hawaiian Ent. Soc., 2 (1908), No. 1, p. 13.

———. Life history of two variable Tortricids. Proc. Hawaiian Ent. Soc., 2 (1908), No. 1, p. 14.

———. Further notes on *Melittobia hawaiiensis*. Proc. Hawaiian Ent. Soc., 2 (1908), No. 1, p. 17.

———. On peculiar deviations from uniformity of habit among Chalcids and Proctotrupids. Proc. Hawaiian Ent. Soc., 2 (1908), No. 1, p. 18.

———. The army worms and cutworms attacking sugar-cane. Hawaiian Sugar Planters' Expt. Sta., Div. Ent. Circ. 5, pp. 21, pls. 3. (May 12, 1908).

TERRY, F. W. Cane borer (*Sphenophorus obscurus*). Hawaiian Planters' Mon., 26 (1907), No. 11, pp. 436-440.

———. The sugar-cane borer (*Sphenophorus obscurus*) in the Hawaiian Islands. Hawaiian Sugar Planters' Expt. Sta., Div. Ent. Circ. 3, pp. 20, pls. 2. (Dec 7, 1907).

———. Notes on the life history of an endemic Hemerobiid (*Nesomicromus vagus* Perk.). Proc. Hawaiian Ent. Soc., 1 (1907), pt. 5, p. 174. (April, 1908).

VAN DINE, D. L., and NÖRGAARD, V. A. Insects affecting live stock in Hawaii. Proc. Hawaiian Live-Stock Breeders' Assoc., 5 (1907), pp. 19-70. 1908.

———. The introduction of honey-producing plants. Hawaiian Forester and Agr., 5 (1908), No. 1, pp. 9-13.

———. Insects and their relation to agriculture. Hawaiian Forester and Agr. 5 (1908), No. 9, pp. 212-216.

——— and THOMPSON, ALICE *R.* Hawaiian honeys. Hawaii Expt. Sta. Bul. 17, pp. 21, figs. 2. (June 30, 1908).

———. Report of the entomologist. Hawaii Expt. Sta. Rpt., 1907, pp. 25-51. Washington, 1908.

REPORT OF THE HORTICULTURIST.

By J. Edgar Higgins.

SHIPPING TROPICAL FRUITS.

The chief work of the year in horticulture was in fruit shipping investigations. The fruits dealt with were pineapple, avocado, papaya, and banana, all of these being shipped to San Francisco. It was demonstrated that pineapples and avocados can be safely shipped as far as Chicago in refrigeration. This experimental shipment of a single carload was followed by two commercial shipments on the part of pineapple growers during the summer of 1908. A carload was sent to Denver and another to Chicago. The results of the experiments of the year 1907 were published in Press Bulletin 21 of the station and details need not be entered into in this report.

THE ORCHARDS.

TILLAGE AND IRRIGATION.

By a rearrangement of water pipes in the orchards tillage and irrigation have been facilitated. These pipes have been laid parallel to the rows of trees, so as not to interfere with tillage. Where possible, irrigation is practiced by the furrow system. A disk harrow is in frequent use and has been found a most efficient implement for maintaining the proper condition in the surface soil. The orchards are now in a more flourishing condition than at any time since they were planted.

COVER CROPS.

In an orchard of tropical fruits cover crops are not less important than in orchard work under temperate zone conditions. In some respects the need here is greater. The rapidity of oxidation of humus necessitates a frequent renewal, and an abundant supply is the more necessary since evaporation proceeds so rapidly. The torrential rains of the wet season render cover crops essential on steep grades to prevent the washing away of the soil. To these benefits will be added a gain in nitrogen if legumes are used.

The best time for sowing a cover crop is at the close of the dry season, as soon as there is sufficient mosture to give the crop a good start. In the months following there will be enough water to supply the needs of the trees and also the cover crop.

The latter may be plowed under just before the close of the wet season. If deep plowing is done after all rains are over, it will result in the loss of much moisture which might have been conserved.

There is one factor in the use of cover crops in the tropics which does not exist in temperate zone conditions. In temperate climates, most trees are dormant in winter, whereas in the tropics the rainy season brings growth even though it come during the coolest portion of the year. For this reason it may be well not to allow the cover crops to come too close to the trees. In the trials which have been made at this station the plants have not been permitted nearer than 5 feet from the trees. This space has been tilled with cultivators.

Many problems connected with the use of cover crops in Hawaii will have to be worked out under local conditions. The station has tested three promising legumes during the year. These were the cowpea (*Vigna catjang*), pigeon pea (*Cajanus indicus*), and jack bean (*Canavalia ensiformis*). Analyses have been made of these, as will be observed by reference to the Report of the assistant chemist.

The cowpea has made the quickest and most luxuriant growth, rapidly covering the ground and reaching maturity much earlier than any of the others. This plant is also recognized as having excellent feeding value either as hay or in the green form. If fed to stock and if the manure is properly cared for, and returned to the land, it is estimated that about 75 per cent of the nitrogen in the crop will be saved. One objection to the cowpea is its susceptibility to the attacks of aphis. These insects did no serious injury to the past year's crop, but at times have been very destructive.

The pigeon pea requires a much longer time to come to maturity. It makes an upright and spreading growth and is difficult to plow under when it has become full grown. If planted far enough apart to develop fully, the pigeon pea becomes too woody for a cover crop. If planted closely, the falling of the dead leaves makes a complete covering for the soil. The leaves of this plant are said to be useful as fodder. The seeds when nearly full grown may be used as a vegetable like green peas, which they closely resemble. The ripened seeds are also much used in the Tropics. The plant appears to be free from serious insect attacks. The jack bean is a plant of lower growth and although it is less rambling than the cowpea, it makes a good cover. It is quite free from insects.

ORCHARD INSECTS.

The chief insects which have required control on the orchard trees have been scales, mealy bugs and aphis. Kerosene emulsion, in the proportion of 1 part of stock solution to 14 parts of water, was used at the suggestion of the entomologist. This

has been found to hold the insects in check and has caused no leaf injury, although used under all conditions of weather.

Another means of reducing the injury due to mealy bugs and aphis has been to apply a tanglefoot mixture to the trunks of the trees, thus arresting the passage of ants.

THE CITRUS ORCHARD.

In December, 1906, a small orchard of seedling citrus trees was planted. The first experimental use of this is to make a test of the adaptability of different stocks, including rough lemon, shaddock (from Hawaiian grown seed), sweet orange, and the pomelo (from California seed). The soil is rather a light loam on a hill slope which is well drained at all times and in summer tends to be dry. In vigor of growth the different species have stood in the order named above. The rough lemon made a very strong growth, far excelling all the other stocks. This of course is only one feature of its character as a stock upon which to bud improved varieties of citrus. The budding of these stocks has begun, the method of trial being to put in each variety in a single tree of every row, thus making the row of a variety run at right angels to the rows of stocks.

BANANAS.

The varieties of bananas which have occupied a part of the land near the laboratories were moved in March to the bottom of a gulch at a higher elevation. This change was made for several reasons. The bananas were occupying too much of the land near the laboratories that was needed for experiments requiring closer observation. The locality was also unfavorable for bananas, being unprotected from the wind. In the new location there is a greater rainfall, and protection from wind is afforded by the adjoining forest.

The requests for offsets, particularly of the Hawaiian varieties, have been so numerous that the stock has been constantly reduced and the most successful fruiting has been prevented. To avoid a repetition of this and to have offsets available, a banana nursery has been planted from which the different varieties can be drawn at times when the removal of offsets from the fruiting plants would be injurious. This nursery consists of large and well fertilized trenches in which offsets are planted closer than would be desirable for fruiting plants.

The following list of forty-three names includes the varieties of bananas now growing on the station lands: Chamaluco, Guaran or Gigante, Colorado or Marado, Colorado Blanco or Marado Blanco, Congo, Enano, Manzano, Platano Harton, Hua Moa, Lahi, Puhi, Ekiula, Moa, Platano Enano, Enano Doble, Datyl or Rosa, Cinerea, Congo Colorado or Congo Marado, Dominico, Pisang Sereh, Gruindy, Pisang Palembang, Pisang

GENERAL VIEW OF MANGO AND AVOCADO ORCHARD.

Mango trees in foreground. Avocados beyond. The mango trees in the centre row which have been cut off have been budded.

Kelat, Apple, Hamakua, Malai-ula, Pisang Mass, Johnson (Santa Domingo) Macho, The Tunis, Manai-ula, Paapu, Ice Cream, Hua Alua, Red Cuban, Brazilian, Largo, Bluefields, Cavendishii from the Canary Islands, Chinese, Custard, Eleele, Lele.

It is probable that a few of the above names are synonyms. We are indebted to the Porto Rico Experiment Station for many of the introduced varieties. The Hawaiian varieties have been collected from different parts of the Territory, through the courtesy of numerous friends of the station. Many of these native varieties are quite out of their natural element on the Island of Oahu and none attain their greatest perfection here. Greater humidity of soil and atmosphere and the freedom from winds afforded by their native haunts render their growth and fruiting more luxuriant.

MANGOES.

BUDDING.

Experiments have been made in the budding of mangoes, with some failures and some very gratifying results. In the case of the variety Alphonse, 80 per cent of the buds have grown. The accompanying illustration shows the growth made from one of the buds 7½ months after it was set and 5 months after growth commenced. (See Pl. III, fig. 1.)

It is interesting to note that a period of over 2 months elapsed between the setting of the bud and its starting into growth, and that this was in early spring when vegetation is active. It is a commonly observed fact that the mango tree makes a sudden new growth, and increases the length of its branches several inches in a few days. It then ceases to grow for several weeks. matures its new wood, and prepares a terminal bud for another sudden increase. The budding must be done in the early part of one of these periods of growth. The bud must then await the next growing period before it can start, as would be the case with summer-budded deciduous fruit trees in the Temperate Zone.

The budding was done on seedling trees about 2½ years old. The method used was that of patch-budding.[a] The buds were set a few inches above the ground and when it appeared probable that a union had been effected between bud and stock the latter was cut through about four-fifths of its diameter, the top being allowed to rest on the ground. After the bud had begun to make new growth the top was completely removed.

Where failures occurred, the result of these trials points to an improper condition of bud wood at the time of the operation as the probable cause. While it is important in all budding that the stock should be in active growth so that the bark will separ-

[a] See Hawaii Sta. Bul. 12.

ate readily from the wood along the line where new cells are being formed, this is even more important in the mango, where a large-sized piece of bark must be removed, leaving an unbroken surface to receive the new bud. With the mango, activity in the bud-wood is as important as in the stock. It is, therefore, necessary to watch the trees from which buds are to be taken and secure bud-wood at just the right period. This appears to be in the earliest stage of rapid growth and continues for only a few days. At this time they should be taken to the orchard and should be set in such trees as are in similar condition. A large majority of the trees will be found to be making a rapid growth at about the same time.

The quality of the bark in varieties appears to differ, some being quite brittle and corky. It may be that patch budding will not prove equally well adapted to all sorts of mangoes.

TRANSPLANTING.

The success with which the transplanting of a mango tree two or more years old can be performed bears an important relation to the methods to be pursued in propagation, and if budding is practiced the degree of success in moving will determine whether the budding must be done on trees in their permanent position in the orchard or may be practiced in nursery row as is done with citrus and deciduous fruit trees.

A few trials were made during the year in the moving of trees about $2\frac{1}{2}$ years old. The test was severe in that it was made during the season of most active growth. All the trees were severely cut back, only the main stem remaining, and of this not more than 18 inches and usually only 6 inches. Some trees were lifted with naked roots and others were balled. None were for a long time out of the ground, and in this respect the test could have been more severe. The results have been quite satisfactory. None of the trees have died and most of them have made a good growth. No difference has been observed between the trees planted with balled roots and those with no soil surrounding them. The trees that were most severely cut back have made the most vigorous growth. While these experiments were not on a sufficiently large scale to justify positive conclusions, their indications are favorable to the handling of the mango as a nursery tree. However, even though this may be quite possible, budding in the orchard may still be more satisfactory.

INARCHING.

Inarching, or grafting by approach, has been practiced to a limited degree. This old and well established method is probably the surest means of propagating fine varieties of mangoes. It is, however, somewhat cumbersome and on a large scale would be expensive.

PLATE III. Fig. 2. Mangosteen, (*Garcinia Mangostana*.)

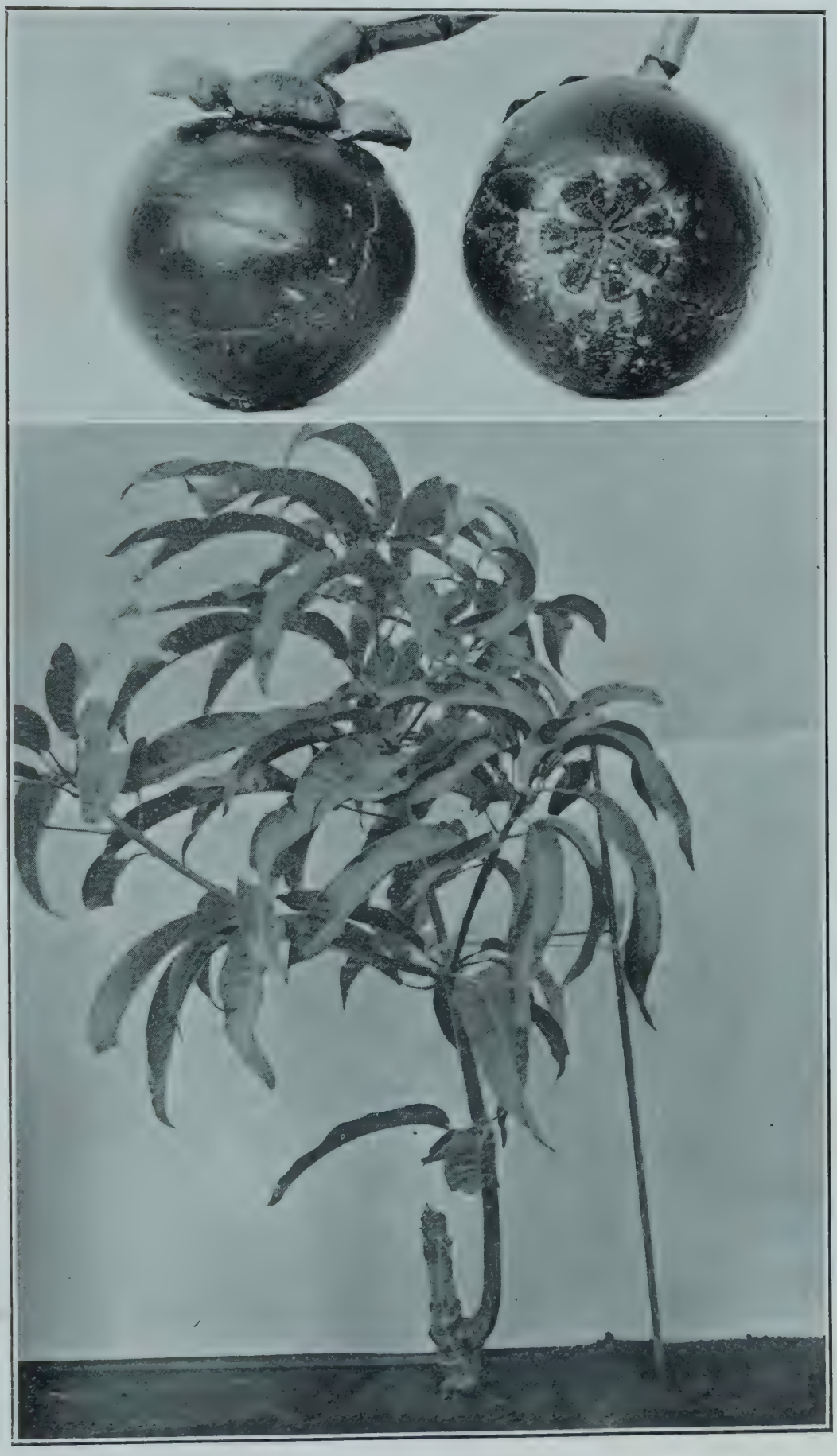


Fig. 1. A budded mango tree 7 1-2 months after the setting of the bud.

SHIPPING BY MAIL.

Shipping young trees by mail has been tried in coöperation with the Office of Seed and Plant Introduction, Bureau of Plant Industry. At different times during the year quite a number of young grafted trees were sent by mail from Washington, D. C., to Honolulu. These were very carefully packed and so far as the moisture of the roots on arrival was concerned, the condition was perfect. The losses, however, were many, due to the withering and dying of immature wood. In most instances also the trees became defoliated in transit or immediately after arrival. The indications were that only trees with firm wood and a dormant terminal bud should be shipped by this method. With such, a good degree of success may be expected.

FLOWERING SEASON.

The season of flowering of the mango in Honolulu has been noted with interest for several years. A record has been kept of the first flowers observed which appeared to be the beginning of a general blooming season, disregarding the few flowers that may appear at almost any time. The record of the beginning of the season has been as follows: January 1 to 10, 1906; December 10 to 12, 1906; November 15 to 20, 1907; and February 15 to 25, 1908. Attention is called to the fact that for three successive years each season of flowering has been nearly one month earlier than in the preceding year. For the mango crop of the summer of 1908 there were two seasons of quite general blooming among the mango trees of Honolulu, the first being in November and the second in February. It will be observed that a period of three months is thus covered which is in marked contrast to the seasons of flowering where climatic conditions are more sharply defined. It will be interesting and instructive to observe the continuation of this cycle.

BORDEAUX MIXTURE FOR BLIGHT.

The use of Bordeaux mixture in the control of mango blight (*Colletotrichum* sp.) has been reported in Bulletin 12, and elsewhere. During the past year some tests were made by Mr. C. J. Hunn, assistant horticulturist and gardener, to determine what strength of the mixture could be used with safety. The following formulas were used:

Formulas for Bordeaux Mixture.

6 lbs. copper sulphate, 6 lbs. lime, and 50 gals. water.
6 lbs. copper sulphate, 5 lbs. lime, and 50 gals. water.
6 lbs. copper sulphate, 4 lbs. lime, and 50 gals. water.
5 lbs. copper sulphate, 5 lbs. lime, and 50 gals. water.

In the case of the third formula considerable leaf injury was observed, and the second was not as satisfactory as the first, more than 5 pounds of lime being necessary to prevent injury from free copper.

PLANT ACQUISITIONS.

Something over 300 numbers have been added to the list of plant acquisitions during the year. Among the more important of these, the following may be mentioned:

"Henequen" (*Agava rigida elongata*). From Missouri Botanic Gardens, through Professor L. H. Dewey, in charge of Fiber Investigations, U. S. Department of Agriculture. The sisal fiber of commerce is derived from plants of the botanical varieties of *Agava rigida*. The present variety is the form commonly cultivated in Yucatan and is said to yield more heavily than the variety *sisalana* but the fiber is of a lower grade. A number of these were distributed and about 400 were planted in nursery row at the station. At first growth was slow, but recently they appear to have become well established.

The parties to whom the distributions were made report that growth has not been nearly so rapid as in the case of the variety *sisalana* under the same conditions. It is however, too early to judge of the merits of the plant as a source of fiber.

PINEAPPLES.

Seven varieties of pineapples of the product of artificial crosses, were received from the Subtropical Laboratory and Garden of the U. S. Department of Agriculture situated at Miami, Florida. The varieties have been described in the 1905 and 1906 Yearbooks of the Department of Agriculture. Those received are as follows: Miami, Deliciosa, Eden, Matthams, Dade, Coquina, and Jensen. Of these, in point of vigor the Eden has ranked first and the Dade second at this station.

ACHOCHA.

Seeds of this Bolivian vegetable were received from Mr. E. M. Ehrhorn, deputy commissioner of horticulture for the State of California. The plants grew vigorously and flowered profusely, but soon after the flowering began, they were completely destroyed by the melon fly.

Sweet sop (*Anona squamosa*), received from Mr. Harry Roberts, Honolulu.

Barleria flava, a yellow flowered ornamental shrub grown from seeds received from the Bureau of Agriculture, Manila.

Sapodilla (*Achras sapota*).

Wampi fruit (*Clausena wampi*). This much esteemed fruit of China and India has been growing in Hawaii in a few gardens for many years, but has never been in general cultivation. The tree is 10 feet to 15 feet in height and produces fruits about $\frac{3}{4}$ to $\frac{7}{8}$ inch in length, and about $\frac{1}{2}$ inch in diameter. It has a straw yellow color and pleasant flavor.

Feijoa sellowiana, a fruit about $2\frac{1}{2}$ inches long and 2 inches thick, with white pulpy flesh said to resemble the guava and the pineapple in flavor. Received from the Couthern California Acclimatization Association.

The cherimoya (*Anona cherimolia*). This highly prized fruit flourishes in a half wild condition in some parts of Hawaii. Quite a large number of seedlings have been grown in the propagating houses for trial at different altitudes on the station tract.

The litchi (*Nephelium litchi*). Two introductions of this species have been made during the year, in each case through the Office of Seed and Plant Introduction. These included three or more of the best Chinese varieties and should make a very valuable acquisition to Hawaiian grown fruits.

Camphor (*Camphora officinalis*). A large number of plants have been grown from seeds received from the Yokohama Nursery Company.

The roselle, variety Victor (*Hibiscus sabdariffa*). A new variety received from the Subtropical Laboratory and Garden, Miami, Florida.

The mangosteen (*Garcinia mangostana*). Pl. III, fig. 2). Two fruits were obtained, in one of which there was a single fertile seed. This has germinated and the seedling is doing well.

The papaya (*Carica papaya*). Four varieties received from Government Stock Gardens, Ceylon.

PLANTS DISTRIBUTED.

The station has continued the practice of distributing seeds and plants of species considered to be worthy of a much more general cultivation and which are not readily obtainable from nurserymen and seedsmen. Among these have been roselle (*Hibiscus sabdariffa*), Bluefields banana, star apple (*Chrysophyllum cainito*) carambola (*Averrhoa carambola*), and many others. At the request of the entomologist, nearly 2,000 mulberry cuttings have been sent to those who are interested in silk production. A record is being kept of all distributions and recipients are expected to report upon the condition of plants entrusted to their care.

MISCELLANEOUS.

Much needed assistance in horticultural work has been provided by the appointment of Mr. Chester J. Hunn to the position of assistant horticulturist and gardener. Mr. Hunn arrived in Honolulu in February, 1908, and began work at once.

The deciduous plantings at the Parker ranch on Hawaii, which were referred to in the last annual report, were visited in March, 1908. At this time all trees requiring it were pruned. The apple and peach trees had made a remarkably vigorous growth at 4,000 feet altitude, and some varieties of peaches were heavily set with fruit buds. The pears, cherries, and apricots had not done so well. At the other orchards the apples and peaches had grown satisfactorily, but not so rapidly as at Waiki, which is at 4,000 to 5,000 feet altitude. The differences, however, appear to be due to other causes than altitude. The soil, situation, and climate at Waiki seem particularly well adapted to the growth of apple and peach trees. It is too early yet to speak of their fruiting and the relation of the flowering season to late frosts.

The greatest hindrances are insects, chief among these being climbing cutworms and Fuller's rose beetle, locally known as "Olinda bug." As a result of these insect attacks a large percentage of the dormant buds was destroyed and the bark from the end of the twigs was eaten. In some instances fully three-quarters of the season's growth was completely stripped. Tree Tanglefoot has since been tried as a means of preventing these injuries, but no reports of its efficiency have yet been received.

The station again coöperated with the Hawaiian Poultry Association in preparing an exhibit of agricultural and horticultural products. The winter season, which is best for a show of poultry, is quite unfavorable for a horticultural exhibition. Nevertheless, a considerable number of interesting things were brought in by the exhibitors.

Some interest has been manifested in the growing of red peppers and an effort has been made to ascertain the probable market for these in the dried form. The wholesale price of these in New York ranges from $7\frac{1}{2}$ to 15 cents per pound. The exact consumption has not yet been ascertained, but it is stated by one company that its annual purchases of cayenne pods amount to several hundreds of tons.

The Waialee Industrial School has grown Tabasco peppers on a small scale. The principal, Mr. T. H. Gibson, estimates that the cost of picking would be about 1 cent per pound. It is too early yet to have any accurate data as to the yields, but it would appear that this is a promising crop. It is certainly a crop that can be marketed at long distances. Several large dealers have requested that a sample of sufficient size for testing be shipped to them.

REPORT OF THE ASSISTANT CHEMIST.

By Alice R. Thompson.

CHEMICAL STUDIES OF RICE AND RICE PRODUCTS.

The principal work of the last year has been that of determining the composition of paddy, straw, and rice grain. Mr. F. G. Krauss, of this station, obtained the samples from rice grown under his direction and from rice imported from Japan for comparison. The question of the food value of rice grown in Japan is rather an important one, the Japanese claiming their rice to be of superior quality as regards richness, hence the preference shown by Japanese to the imported rice.

The samples analyzed were of three kinds of rice—one, the imported Japan rice, another the Hawaiian grown rice of the Japan variety, and the third, Hawaiian Gold Seed rice grown in Hawaii.

Each kind of rice was divided into two samples, one of rice thoroughly polished; the other, of rice still "in the brown."

The analyses of the rices are as follows:

Composition of different kinds of rice.

[Air-dry material.]

Variety	Water.	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	Ash.
Polished.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Imported Japan	13.72	6.39	0.64	76.76	1.81	0.68
Station-grown Japan	13.05	6.47	.71	76.66	2.24	.87
Hawaiian (Gold Seed)	14.10	6.78	.46	76.86	1.32	.48
In Brown						
Imported Japan	13.40	7.09	2.08	73.87	2.22	1.34
Station-grown Japan	13.02	6.79	2.10	74.09	2.35	1.65
Hawaiian (Gold Seed)	13.79	7.14	2.13	72.87	2.74	1.33

Composition of different kinds of rice.

[Dry-matter basis.]

Variety.	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	Ash.
Polished.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Imported Japan	7.40	0.74	88.97	2.10	0.79
Station-grown Japan	7.44	.82	88.16	2.58	1.00
Hawaiian (Gold Seed)	7.89	.54	89.47	1.54	.56
In Brown.					
Imported Japan	8.18	2.40	85.31	2.56	1.55
Station-grown Japan	7.81	2.41	85.18	2.70	1.90
Hawaiian (Gold Seed)	8.28	2.47	84.53	3.18	1.54

As may be noticed, there is no very great difference in the chemical composition of the rices. Especially is this true where the polished rices are compared separately with the unpolished. It was to be expected, since the bran of rice is high in fat and protein, that the unpolished rice should have a higher fat and protein content than the polished. Comparing the rices, it is noticeable that the unpolished rice has from three to four times as much fat as the polished, and the protein content is from 0.8 to 0.4 per cent higher in the unpolished. The ash and fiber are also higher in the unpolished.

But as far as the varieties are concerned there is but little increase of food value in the Japan imported rice as compared with the Hawaiian grown rice, Japan or Hawaiian standard seed. In the polished condition there is about 0.4 per cent more fat in the Japan variety, but about 0.5 per cent more protein in the Hawaiian variety (comparing the results as set forth in the "water-free material" table). In the unpolished condition the protein and fat contents of the three samples are almost identical.

The nitrogenous constituents of the rices are shown in the following table:

Nitrogenous constituents of rice.

[Fresh material.]

Variety.	Total Nitrogen.	Proteid nitrogen.	Amid nitrogen.	Crude protein (total N x 6.25)	True protein (proteid N x 6.25)	Amids calculated as asparagin.
Polished.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Imported Japan	1.022	1.022	.....	6.39	6.39	.....
Station-grown Japan	1.035	1.035	.....	6.47	6.47	.....
Hawaiian (Gold Seed)	1.085	1.085	.....	6.78	6.78	.....
In Brown.						
Imported Japan	1.134	1.126	0.008	7.09	7.04	0.04
Station-grown Japan	1.087	1.081	.006	6.79	6.76	.03
Hawaiian (Gold Seed)	1.142	1.142	.....	7.14	7.14	.....

It will be seen that there is little or no difference between the total nitrogen and albuminoid nitrogen.

During the ensuing year, analyses will be made of other rices, but the work already indicates that the claim for the superiority of Japan imported rice over Hawaiian-grown rice will not hold so far as the nutritive value of the rices is concerned.

Analysis of rice paddy and straw of rices grown from seed of different varieties was made, also of rice of the same variety grown under different conditions. Samples were taken and dried by Mr. F. G. Krauss and sent to this laboratory for analysis.

The Japan Seed rice paddy has the lowest protein value. The Japan Seed rice and the dry-land grown rice contain a little more fat than the Gold Seed, and about 4 per cent more fiber. Studying the ash constituents, the Japanese rice and the dry-land grown rice contain the highest percentage of potash,—the Japan the least phosphoric acid,—the Hawaiian rice the most lime. The magnesia is about the same all through.

In one case the dry-land rice variety was grown under wet-land conditions. Under these conditions the protein and fiber became less, the lime a little higher, but no other especial change was produced.

The composition of the rice straw is not so definite as that of the paddy. Rice of the same variety varies. From the following tables, however, it is seen that the dry-land rice grown under dry-land conditions has less fiber but higher protein content than the other rice.

Composition of rice hay (straw and paddy).

[Air-dry material].

Variety of rice.	Proximate constituents.						Ash constituents.				
	Water.	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	Ash.	Potash.	Soda.	Lime.	Phosphoric acid.	Magnesia.
	Per Cent.	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*
Japan Seed, grown at Kailua	9.85	4.04	1.67	46.02	24.30	14.12	1.567	0.288	0.547	0.323	0.219
Japan Seed, grown at station trial grounds	9.11	4.03	1.69	45.40	23.80	15.97	1.381	.273	.296	.364	.202
No. 65 (dry-land grown)	10.26	6.38	1.96	42.40	23.30	15.70	1.370	1.40	.264	.693	.....
No. 68 (dry-land grown)	10.28	6.29	1.60	49.28	18.84	13.71	1.082	1.20	.214	.726	.....
Standard Hawaiian Gold Seed, grown at trial grounds	9.72	4.21	1.47	43.48	24.81	16.31	1.850	.276	.350	.320	.259
Standard Hawaiian, grown at Palama	9.86	3.45	1.66	43.00	27.74	14.29	1.614	.641	.349	.280	.160
No. 65 grown under wet-land conditions	9.64	3.76	1.65	47.08	25.31	12.56	1.228	.330	.386	.381	.188

Composition of rice hay.

[Dry-matter basis.]

Variety of rice.	Proximate constituents.					Ash constituents.				
	Protein.	Fat	Nitrogen-free extract,	Crude fiber.	Ash.	Potash.	Soda.	Lime.	Phosphoric acid.	Magnesia.
	Per Cent.	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*
Japan Seed, grown at Kailua	4.48	1.85	51.06	26.95	15.66	1.738	0.319	0.607	0.358	.0243
Japan Seed, grown at station trial grounds	4.43	1.86	51.96	26.18	15.57	1.519	.300	.326	.400	.222
No. 65 (dry-land grown)	7.09	2.18	47.28	25.96	17.49	1.526	1.560	.294	.772	.....
No. 68 (dry-land grown)	6.97	1.78	54.99	20.99	15.27	1.205	1.337	.238	.809	.....
Standard Hawaiian Gold Seed, grown at trial grounds	4.66	1.63	48.19	27.46	18.06	2.048	.306	.387	.354	.287
Standard Hawaiian, grown at Palama	3.83	1.84	47.72	30.76	15.85	1.790	.711	.387	.311	.177
No. 65 grown under wet-land conditions	4.16	1.82	52.14	27.99	13.89	1.358	.365	.427	.421	.208

Nitrogenous constituents of rice.

[Air-dry material.]

	Total nitrogen.	Proteid nitrogen.	Amid nitrogen.	Crude protein (total N x 6.25).	True protein (proteid N x 6.25).	Amids calculated as asparagin.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Paddy.						
Japan Seed (Kailua)	0.938	0 936	0.002	5.86	5.85	0.01
Japan Seed (trial grounds)	.990	.962	.028	6.19	6.01	.13
Dry-land No. 65	1 667	1.462	.205	10.42	9.14	.96
Dry-land No. 68	1.247	1.247	.000	7.79	7.79	.00
Standard Hawaiian (trial grounds)	1.382	1.381	.001	8.64	8.63	.01
Standard Hawaiian (Palama)	1.117	1.117	.00	6.98	6.98	.00
Dry-land No. 65 grown under wet-land conditions	1.094	1.094	.00	6.84	6.84	.00
Straw.						
Japan Seed (Kailua)	.400	.....	.....	2.50	.....	.....
Japan Seed (trial grounds)	.472	.403	.059	2.950	2.520	.32
Dry-land No. 65	.696	.585	.111	4.35	3.66	.52
Dry-land No. 68	.768	.744	.024	4.80	4.65	.11
Standard Hawaiian (trial grounds)	.438	.391	.047	2.74	2.44	.22
Standard Hawaiian (Palama)	.327	.289	.038	2.04	1.81	.18
Dry-land grown under wet-land conditions	.405	.364	.041	2.53	2.28	.19
Hay.						
Japan Seed (Kailua)	.646	.....	.....	4.04	.....	.....
Japan Seed (trial grounds)	.644	.589	.055	4.03	3.68	.26
Dry-land No. 65	1.019	.877	.142	6.37	5.48	.67
Dry-land No, 68	1.007	.995	.012	6.29	6.22	.06
Standard Hawaiian (trial grounds)	.674	.638	.036	4.21	3.99	.17
Standard Hawaiian (Palama)	.552	.525	.027	3.45	3.28	.13
No. 65 grown under wet-land conditions	.602	.572	.030	3.76	3.58	.14

Composition of paddy.

[Air-dry material.]

Variety of rice.	Proximate constituents.						Ash constituents.				
	Water.	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	Ash.	Potash.	Soda.	Lime.	Phosphoric acid.	Magnesia.
	Per Cent.	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*
Japan Seed, grown at Kailua	12.01	5.86	1.97	63.32	10.86	5.98	0.511	0.069	0.080	0.577	0.206
Japan Seed, grown at station trial grounds	11.47	6.19	1.95	64.46	10.25	5.68	.503	.119	.090	.660	.235
No. 65 dry-land grown	11.54	10.42	2.19	59.36	10.84	5.65	.470	.114	.113	.740	.....
No. 68, dry-land grown	11.30	7.79	1.77	61.52	10.30	7.32	.438	.125	.106	.785	.....
Standard Hawaiian Gold Seed, grown at station trial grounds	11.58	8.64	1.47	64.46	7.46	6.39	.370	.023	.140	.692	.211
Standard Hawaiian Gold Seed, grown at Palama	11.78	6.98	1.64	66.30	7.66	5.64	.346	.095	.170	.698	.235
No. 65 grown under wet-land conditions, at Palama	11.93	6.84	1.86	65.47	8.20	5.70	.449	.069	.170	.730	.246

Composition of paddy.

[Dry-matter basis.]

Variety of rice.	Proximate constituents.					Ash constituents.				
	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	Ash.	Potash.	Soda.	Lime.	Phosphoric acid.	Magnesia.
	Per Cent.	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*
Japan Seed, grown at Kailua	6.66	2.24	71.97	12.34	6.79	0.583	.078	.091	0.655	0.234
Japan Seed, grown at station trial grounds	6.99	2.20	72.83	11.57	6.41	.568	0.134	.102	.745	0.265
No. 65, dry-land grown	11.78	2.47	67.12	12.25	6.38	.531	0.129	.128	.836	.....
No. 68, dry-land grown	8.78	1.99	69.37	11.61	8.25	.494	0.141	.119	.885	.....
Standard Hawaiian Gold Seed, grown at station trial grounds	9.77	1.66	72.90	8.44	7.23	.418	.26	.158	.783	.239
Standard Hawaiian Gold Seed, grown at Palama	7.89	1.85	75.23	8.66	6.37	.391	.107	.192	.789	.266
No. 65, grown under wet-land conditions at Palama	7.76	2.11	74.35	9.31	6.47	.510	.078	.193	.829	.279

Composition of rice straw.

[Air-dry material]

Variety of rice.	Proximate constituents.						Ash constituents.				
	Water.	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	Ash.	Potash.	Soda.	Lime.	Phosphoric acid.	Magnesia.
	Per Cent.	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*
Japan Seed, grown at Kailua	8.77	2.50	1.52	37.99	31.02	18.20	2.096	0.398	0.625	0.197	0.181
Japan Seed, grown at station trial grounds	8.25	2.95	1.57	35.51	30.59	21.13	1.821	.350	.400	.216	.185
No. 65, dry-land grown	9.62	4.36	1.84	33.92	29.53	20.73	1.820	.154	.340	.670	.....
No. 68, dry-land grown	9.26	4.80	1.44	37.01	27.39	20.10	1.727	.115	.323	.667	.....
Standard Hawaiian Gold Seed, grown at station trial grounds, (wet-land)	9.10	2.74	1.48	36.48	30.59	19.61	2.350	.361	.420	.197	.275
Standard Hawaiian Gold Seed, grown at Palama (wet-land)	9.09	2.04	1.67	33.68	35.77	17.75	2.121	.860	.420	.114	.130
No. 65, grown under wet-land conditions at Palama	8.72	2.53	1.56	37.44	32.16	17.59	1.540	.435	.473	.242	.166

Composition of rice straw.

[Dry-matter basis.]

Variety of rice.	Proximate constituents.					Ash constituents.				
	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	Ash.	Potash.	Soda.	Lime.	Phosphoric acid.	Magnesia.
	Per Cent.	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*
Japan Seed, grown at Kailua	2.74	1.67	41.64	34.00	19.95	2.297	0.436	0.685	0.216	0.198
Japan Seed, grown at station trial grounds	3.21	1.71	38.76	33.31	23.01	1.983	.381	.463	.235	.201
No. 65, dry-land grown	4.81	2.04	37.56	32.66	22.93	2.013	.170	.376	.741	.....
No. 68, dry-land grown	5.29	1.59	40.79	30.18	22.15	1.903	.127	.356	.735	.....
Standard Hawaiian Gold Seed, grown at station trial grounds, (wet-land)	3.01	1.63	40.14	33.65	21.57	2.585	.397	.462	.217	.303
Standard Hawaiian Gold Seed, grown at Palama (wet-land)	2.31	1.84	37.03	39.31	19.51	2.331	.945	.461	.125	.143
No. 65, grown under wet-land conditions at Palama	2.77	1.71	41.04	35.22	19.26	1.686	.476	.518	.265	.182

As for its ash constituents, the dry-land variety of straw takes up less lime but much more phosphoric acid than the other rices.

In case the dry-land variety is grown under wet-land conditions, the crude fiber and lime increase and the protein and phosphoric acid decrease. There is not much difference between the Japan wet-land rice and the Hawaiian wet-land rice.

The composition of rice hay is calculated from the analyses of both paddy and straw, knowing the proportion of paddy to straw. Only the dry-land rice hay is at present of practical importance as it can be most cheaply grown. As it has the highest protein content, it will be of more value as a fodder.

MISCELLANEOUS FODDERS.

Besides the analyses of several samples of rice hay as fodder, two samples of Rhodes grass, one of cassava waste, three of leguminous plants, and one of American wheat hay were analyzed.

The Rhodes grass, compared with the wheat hay, contains a higher percentage of protein, about the same amount of fat, fiber and ash, and about twice as much lime.

The legumes (tops analyzed) have an especially high protein content, the pigeon pea containing the most nitrogen. The fat content of the cowpea is lower than that of American cowpeas, but the jack bean and pigeon pea contain a good deal of fat (as estimated by ether extraction). The cowpea has a higher fiber content than the average pea grown in America.

The legumes were grown on the station grounds and the yields per acre, estimated by Mr. F. G. Krauss, are as follows: Cowpea, 17,000 to 22,000 pounds; pigeon pea, 8,100 to 11,000 pounds; jack bean, 11,000 to 15,000 pounds.

The analyses of the fodders are given in the following tables:

Composition of miscellaneous fodders.

	Proximate constituents.						Ash constituents.		
	Water.	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	Ash.	Potash.	Lime.	Phosphoric acid.
Air-dried.	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*
Rhodes grass hay	11.75	6.08	2.31	42.51	30.20	7.15	1.314	0.730	0.280
Rhodes grass hay	9.87	7.25	1.39	44 64	29.21	7.64	.....	.805	.....
Wheat hay	9.44	4.48	1.82	45.14	31.80	7.32	.....	.375	.....
Fresh material.									
Cow-pea (*Vigna cat jang*)	83.15	3.71	.22	5.26	5.75	1.91	.681	.290	.183
Pigeon-pea (*Cajanus indicus*)	70.00	7.11	1.65	7.88	10.72	2.64	.904	.428	.259
Jack bean (*Canavalia ensiformis*)	76.81	5.21	.48	8.44	6.36	2.70	.650	.780	.162

Composition of miscellaneous fodders.

[Dry-matter basis.]

	Proximate constituents.				Ash constituents.		
	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	Potash.	Lime.	Phosphoric acid.
Rhodes grass;	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*
Sample No. 1	6.88	2.62	48.19	34.21	1.49	0.83	0.32
Sample No. 2	8.07	1.54	49.53	32.39	.....	.892	.....
Cassava	1.36	.58	87.36	9.06	.32	.470	.117
Cow-pea (*Vigna cat jang*)	21.99	1.33	31.20	34.15	4.04	1.72	1.087
Pigeon pea, (*Cajanus indicus*)	23.69	5.51	26.26	35.73	3.014	1.425	.862
Jack bean (*Canavalia ensiformis*)	22.44	2.08	36.42	27.42	2.801	3.365	.697
Wheat hay	4.95	2.01	49.84	35.12	.....	.414	.....

Nitrogenous constituents of miscellaneous fodders.

(Fresh material).

	Total Nitrogen.	Proteid Nitrogen.	Amid Nitrogen.	Crude protein (total N x 6.25).	True protein (proteid N x 6.25).	Amids calculated as asparagin.
Rhodes grass:	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Sample No. 1	.972	0.760	0.212	6.08	4.75	1.00
Sample No. 2	1.160	.956	.204	7.25	5.98	.96
Cassava	.190	.190	.....	1.19	1.19	.....
Cowpea (*Vigna catjang*).	.593	.424	.169	3.71	2.65	.80
Pigeon pea (*Cajanus indicus.*).	1.137	.998	.139	7.11	6.24	.65
Jack bean (*Canavalia ensiformis*).	.833	.629	.204	5.21	3.93	.96
Wheat hay	.717	.611	.106	4.48	3.82	.50

FERTILIZER ANALYSES.

But five samples of materials intended for fertilizers have been analyzed as follows:

Analyses of Fertilizer Materials.

Fertilizer Materials.	Moisture.	Phosphoric Acid.	Potash.	Nitrogen.	Lime.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Castor pomace	10.72	1.818	1.310	5.190	1.02
Peanut meal	10.59	1.642	1.284	8.360	.46
Cowpea (*Vigna catjang*)	83.15	.101	.408	.526	.491
Pigeon pea (*Cajanus indicus*)	70.00	.202	.788	.783	.312
Jack bean (*Canavalia ensiformis*)	76.81	.218	.783	.723	.438

The castor pomace and peanut meal were imported from China. It is believed that neither the pomace nor the meal will ever come into general use in these islands, as commercial fertilizers are extensively used and apprecited; and the more inferior organic fertilizers cannot take their place.

The legumes (whole plant analyzed) have a high nitrogen content. The analyses of the cowpea grown at this station show a higher content of nitrogen, phosphoric acid, and potash than that found in cowpeas grown in America. The jack bean compares favorably with the cowpea in composition. The pigeon pea (a tropical plant) and the jack bean contain the most nitrogen. These legumes may be especially appropriate as fertilizers for Oahu coast soils, where the humus is deficient.

The yields per acre of legumes (roots included) raised at this station were as follows: Cowpea, 18,000 to 23,000 pounds; pigeon pea, 9,000 to 12,000 pounds, and jack bean, 15,000 to 19,000 pounds.

SOILS.

A number of samples of soils were analyzed during the year, as follows:

Analysis of samples of Hawaiian soils.

No. of sample	Moisture.	Organic matter and combined water.	Nitrogen.	Phosphoric acid.	Potash.	Lime.	Magnesia.	Manganese oxide.
	Per Cent	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*
1	14.141	.....	0.505	0.185	0.178	0.59	1.622	0.115
2	15.263	.....	.555	.277	.151	.69	2.204	.130
3	3.763	15.864	.295	.127	.547	.940	.450	.400
4	9.429	10.441	.193	.223	1.553	3.29	.....	.120
5	.....	.....	.148	.....	.254	.57	.....	.....
6	8.907	14.726	.328	.198	.248	2.280	1.672	.120
7	7.536	13.660	.226	.127	.148	1.720	1.564	.130

The two soils, Nos. 1 and 2, are pineapple soils obtained from a field near Hilo, Hawaii. No. 1 is a brown loam, acid in reaction, taken from the Hamakua end of the field; No. 2 is also a brown loam, acid to litmus, and taken from the Puna end. The lime content is low in both soils, which fact accounts for the acidity noticed. The potash is low also.

Soil No. 3 came from upper Hoaeae and is a dark red loam, neutral in reaction with litmus. It contains a great abundance of humus; the nitrogen and potash are high; the lime rather low for the kind of soil, and the phosphoric acid low for a Hawaiian soil. Pineapples are growing well on the land.

No. 4 comes from land near Diamond Head and is a brown clay loam, effervescing with acid, showing presence of calcium carbonate. The humus is very low, scarcely coloring the potash solution. Results indicate that the lime is high, the phosphoric acid and nitrogen fair, and the potash abnormally high (sample may be an abnormal one). A crop of legumes grown and turned under on the land would probably improve the land, as there is very little humus.

Another soil from land near Diamond Head was also examined and proved to contain no humus at all. A large amount of effervescence followed action of acid on the soil, showing

presence of much calcium carbonate. This soil contained but 0.098 per cent nitrogen.

Soil No. 5 came from the Palama district of this island, and is a red clay loam, neutral to litmus. The soil is rather low in potash and lime.

One soil was obtained from Palolo Valley and lime advised for it, as it was found to be quite acid.

The nitrogen was determined in five rice soils of Oahu and is as follows: Kailua, 0.186 per cent; Palama, 0.328 per cent; Punaluu soils toward litmus was acid, that of the station trial trial grounds, 0.224 per cent. The reaction of the Kailua and Punaluu soils toward litmus was acid, that of the station trial grounds slightly acid, and that of the Palama and Waikiki soils neutral.

Soils Nos. 6 and 7 are rice soils, obtained from Palama and Punaluu, respectively. No. 6 is a brown clay loam, and the analysis indicates a small deficiency of potash, while the lime is high. No. 7 is a dark brown loam and is deficient in potash and phosphoric acid, but high in lime. In both soils the lime content is higher than the magnesia, which relation is often found reversed in Hawaiian soils.

WATER ANALYSES.

One sample of irrigation water from Hilo was analyzed and found to contain 78.27 grains of total solids, and 35.23 grains of salt per gallon. This explained the dying of young fruit trees irrigated with this water.

Fourteen samples of drainage water from a rice lysimeter experiment were analyzed for potash, phosphoric acid, magnesia, lime, and nitrogen. The results indicate that ammonium sulphate used as a fertilizer causes loss of lime in the soil. Addition of magnesium salts causes an increase of magnesia in the drainage water. Only traces of phosphoric acid were found in the sample of water.

MISCELLANEOUS WORK.

The wax left in slum gum from which wax had been extracted by a new method was determined. Only 25.27 per cent wax was found. The percentage of slum gum left on extraction was also very small.

A sample of koa bark sent from Hawaii contained 19.91 per cent tannin in the water-free material. A sample of ohia bark had but 5.73 per cent tannin in the water-free state. No further effort has been made by those interested in koa bark to obtain tannin.

A fertilizer experiment was carried out with rubber plants, using paraffin pots and fertilizers, according to the wire-basket

method devised by the Bureau of Soils of the U. S. Department of Agriculture.[a]

The soil used was from station land. The idea was to study the effects of different fertilizers on the rubber plant of the Para variety in soil of station land type. The results are as follows:

(*Pot Experiments with fertilizers for Para rubber.*)

Fertilizer used.	Average transpiration.	Average weight of plant.
	Grams.	*Grams.*
Check	10.95	3.14
Phosphoric acid	11.56	3.42
Sulphate of potash	11.42	3.55
Nitrate of soda	16.58	3.90
Lime	13.05	3.22
Manure	15.50	3.56
Phosphoric acid and sulphate of potash	17.16	3.83
Phosphoric acid and nitrate of soda	10.50	3.40
Nitrate of soda and sulphate of potash	13.20	3.29
Phosphoric acid, lime, nitrate of soda, and sulphate of potash	7.06	2.45
Phosphoric acid, nitrate of soda, and sulphate of potash	12.35	3.18

Where manure, sodium nitrate, or lime was the single fertilizer the transpiration increased materially. Acid phosphate or potassium sulphate alone gave but a slight increase. The combinations of acid phosphate and potassium sulphate gave a large increase, but acid phosphate in the other combinations either decreased the transpiration or gave but little increase.

An experiment with Ceara rubber was carried out. The best results were obtained with lime, sodium nitrate, and the two combinations, sodium nitrate and potassium sulphate, and sodium nitrate, potassium sulphate, and acid phosphate. Manure alone and potassium sulphate alone gave fair results. Acid phosphate,

[a] U. S. Dept. Agr., Bur. Soils Circ. 18.

except in the one combination already cited, gave poor results. These pot experiments indicate that sodium nitrate used alone makes a good fertilizer for rubber trees, while acid phosphate has some deleterious effect upon them.

FIELD CROP EXPERIMENTS.

By F. G. Krauss.

The following subjects are treated in this report: Rice investigations, including tests of old and new varieties; fertilizer experiments, upland rice as a hay and grain crop, and salt marsh rice hay experiments; Chinese and Japanese mat rush experiments; cotton experiments; soy beans; peanuts; and Leghorn wheat.

RICE INVESTIGATIONS—REPORT OF SECOND YEAR'S EXPERIMENTS.

INTRODUCTION.

The rice experiments covering the past year are a continuation of the investigation begun two years ago. The work has thus far followed closely the original outline as set forth in A Preliminary Report on Rice Investigations. (See Pl. IV). In the search for rotation and substitute crops for our rice lands, a number of new crops are being tested. Among these may be mentioned the Chinese and Japanese mat sedges for the lowlands; cotton for the dry uplands; soy beans and peanuts for intermediate conditions.

A brief sketch of the rice industry in Hawaii appeared in the first report of these investigations.

Industrial and commercial statistics of the industry, compiled from original sources, are given herewith for reference.

THE MILLING INDUSTRY.

The milling of rice is not confined to the Chinese, as is the cultural phase of the industry. One of the largest and most modern of the rice mills is conducted by Mr. H. E. Walker in Honolulu. Another large modern mill is that of the City Mill Company, of which Mr. Chung K. Ai is manager. The Japanese Rice Mill Company is another large Honolulu concern which mills imported Japan rice exclusively.

The maximum capacity of the largest mills is about 100,000 bags of clean rice per annum. As two crops are harvested during the year, besides the large importations of Japan rice in the "brown," the larger mills are run during a large part of the year. The majority of the fifty odd mills in the islands are of antiquated Chinese pattern, the product of which does not equal the highly finished American article, which is not sought by the oriental trade of Hawaii.

Below is given a list of the principal Hawaiian rice mills having a capacity of 10,000 or more bags clean rice per annum. Honolulu is the principal milling center.

Principal rice mills of Hawaii.

Name of mill.	Location.	Type of Mill.	Approximate capacity (clean rice)	Kind of Rice. milled.	
				Hawn.	Japanese
	OAHU.		*Bags.*	*Bags.*	*Bags.*
City Mill Co	Honolulu	Modern	45,000	15,000	30,000
C. Ah Loong Mill	do	Antiquated	10,000	7,000	.....
Iwilei Rice Mill	do	do	10,000	10,000	.....
Japanese Rill Mill Co.	do	Modern	100,000	.....	100,000
Kaalaea (Sing Chong Co)	Heeia	Antiquated	13,000	13,000	.....
Kaneohe Rice Mill Co. Ltd	Kaneohe	Modern	16,000	16,000	.....
Kimura S. Rice Mill	Honolulu	do	20,000	.....	20,000
Waialua Rice Mill (Sing Chong Co)	Pearl City	Antiquated	26,000	26,000	.....
Walker's Rice Mill	Honolulu	Modern	68,000	3,000	65,000
Wing Chong Can Co	do	Antiquated	14,000	14,000	.....
Wong Kwai Mill	Punaluu	do	12,000	12,000	.....
Wong Leong Rice Mill	Waimanalo	do	11,000	8,000	3,000
	KAUAI.				
Hee Fat	Hanalei	.....	4,200	.....	.....
Hee Fat	Kapaa	.....	11,250	.....	.....
Man Sing Co	Hanalei	.....	11,000	.....	.....
Pah On Mill	Waimea	.....	16,000	.....	.....

The total yield of rice on the Island of Hawaii does not exceed 11,000 bags clean rice per annum. The Palolo Rice Mill Kohala, mills about 3,000 bags; Waipio Rice Mill at Kukuihaele, mills about 6,000 bags; Halawa Rice Mills, about 2,000 bags. The island of Maui grows and mills less than 5,000 bags and Molokai only about 500 bags per annum.

Comparatively little of the 50,000,000 pounds of rice grown in Hawaii is exported from the islands. The imports of Japan rice are large. The amount of rice imported from the United States is about equal to that exported from Hawaii.

PLATE IV. Fig. 1. Uniform planting in rice experiments.

Fig. 2. Seven types of Japan rice

Below are given the U. S. customs statistics covering the imports and exports of rice to and from Hawaii for the five years ending June 30, 1907.

Imports of rice into Hawaii.

Year.	Japan.		China.		United States.	
	Amount.	Value.	Amount.	Value.	Amount	Value.
	Pounds.	*Dollars.*	*Pounds.*	*Dollars.*	*Pounds.*	*Dollars.*
1903	10,194,030	234,273	58,125	926	2,209,920	102,008
1904	19,044,460	443,920	341,113	4,449	3,642,925	143,142
1905	9,656,796	221,116	11,964	245	9,983,491	303,029
1906	12,496,396	283,653	22,600	529	4,129,643	164,683
1907	21,012,842	539,021	13,906	351	755,050	34,144

The exports to the United States from Hawaii during the same period were:

Exports of rice to the United States from Hawaii.

Year.	Amount.	Value.
	Pounds.	*Dollars.*
1903	234,930	$10,218.00
1904	31,911	1,610.00
1905	2,771,083	84,414.00
1906	5,739,500	223,012.00
1907	3,324,107	147,439.00

Acknowledgement is made of the valuable assistance and coöperation of rice planters, station workers, and others who have aided in the past year's experiments. The station's thanks are also due the Hawaiian Fertilizer Company and The Pacific Guano and Fertilizer Company, of Honolulu, for their liberal donation of fertilizers used in the past two year's experiments.

TEST OF OLD AND NEW VARIETIES OF RICE.

During the past year a third comparative test was made of some 130 varieties of rices originally obtained from the U. S. Department of Agriculture through the Office of Experiment Stations. This experiment completes two fall and one spring test of a representative list of varieties. Another spring test is planned for 1909 and the data of the four tests will be compiled in the form of a classified descriptive list.

The past season was favorable to growth and the same general cultural methods were adopted as in former tests. As in

the two preceding tests, all the stocks were selected from individual mother plants; two such selections were sown of each variety, the object being to double the range of selection. On the whole, this test again demonstrates the good results to be obtained from careful selection.

As in the previous tests, all the varieties came true to type, thus confirming our original observations that natural hybridization does not readily take place in the field.

While a number of varieties might be eliminated at this time, it seems best that a fourth and final test be made before discarding any of the varieties now under test.

During the year, pure strains of the most promising varieties of last year were grown in quantity and disseminated among the rice growers generally. Of these, variety No. 19 (S. P. I. Inv. No. 12508), said to have been experimentally grown at the Georgetown Botanical Gardens from imported Ceylon stock, has thus far proved the most noteworthy. This variety proved very uniform in type from the start. The mother plant, selected from among the first progeny, produced 26 fruiting culms, which yielded 59 grams paddy, numbering 1,176 seeds. Two hundred plants in the test row produced over 17 pounds of paddy; and 10 pounds of stock seed transplanted to one-third acre, yielded 1,680 pounds choice paddy, on unfertilized land. This represents an increase of 168 fold and an acre yield of 5,040 pounds paddy under field conditions.

The culinary qualities of rice No. 19 are excellent. The milled grain is long, slender, hard and translucent, a type highly prized by the Chinese upper class. Considering the type, the milling qualities are fair, the paddy yielding about 62 per cent of prime rice. This rather large loss in milling is principally due to the unusually long slender grains which fracture in the process of hulling.

Variety No. 19 is suitable for fall culture only. July and August plantings mature in from 120 to 140 days. When planted in the spring it continues to vegetate till late in the fall and matures with late planted crops. As this variety tillers extraordinarily, 80 fruiting culms having been obtained from a single seed, with 25 as an average, not more than two or three seedlings should be set in a clump at transplanting.

A carefully developed strain of Japan rice, No. 153, now in its fourth generation of selection, is meeting with much favor among the several growers who have tried it. It matures in 110 days from planting, and yields equally with the more slowly maturing Hawaiian type of Gold Seed. The Japanese, who are the principal consumers of the Japan Seed rice, appear to regard the locally grown product with less prejudice, as its quality becomes better known.

In this connection, the chemical composition of the Japan and Hawaiian grown stocks is of interest. It was claimed by the Japanese that the local product lacked in "strength," "richness,"

and "fattiness," as well as flavor. The following analyses were made by the Bureau of Chemistry, U. S. Department of Agriculture, and confirm the analyses made by this station:

Chemical analyses of imported and Hawaiian grown Japan rices.

	Moisture.	Protein (N x 6.25)	Fat.	Carbohydrates by difference.	Crude fiber.	Ash.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Imported Japan (in brown)...	10.97	7.19	2.08	77.53	1.02	1.21
Hawaiian grown Japan (in brown).....	10.40	7.38	2.23	77.26	1.07	1.66
Imported Japan (fully milled)	11.16	6.63	.38	80.91	.46	.49
Hawaiian grown Japan (fully milled).....	10.76	7.31	.58	79.93	.60	.82

A comparison of the above data shows that instead of being inferior to the imported product, the Hawaiian grown Japan rice contains a higher percentage of fat and nitrogenous matter, the properties that would seem to determine the so-called "richness," "fattiness," and "strength."

A selection from variety No. 39 (S. P. I. Inv. No. 12582), a Georgia strain of Gold Seed, continues to gain headway against the Hawaiian type of this standard form of rice.

Variety No. 65 (S. P. I. Inv. No. 17144), the Egyptian variety similar to the Japan type, maintains its excellent yielding qualities, but is not liked by the Japanese consumers, who claim that it lacks in flavor. Besides, it is slower in maturing than the Japan sorts, which now produce satisfactory yields. However, this variety is especially well adapted for use as a hay crop, it is nutritious, the hulls of the seed are smooth, and the kernel is soft. It succeeds well with a minimum amount of irrigation. At a lower price than is asked for standard sorts, large quantities of the grain would be used in the manufacture of the Japanese food product, "Miso."

Variety No. 152, the Ay-Yujip rice, from the Igorrote country, Philippine Islands, which gave exceptional promise in the first comparative test, failed utterly in an extensive planting at Punaluu, along side of variety No. 19. While the general growth was satisfactorily, it failed to set seeds. Grown at the trial grounds near Honolulu, the results, while not equal to the first test, were fairly good. No explanation can be offered for this difference in behavior except that the excessive winds prevailing during the flowering season may have prevented pollination. No. 73, a Philippine rice called "Mokalit," of the Chinese "No-mai" type, also yielded well.

Five new Japan rices, three of which, Nos. 161, 162, and 163, were kindly sent to the station by Dr. Y. Otsuka, Chief of the Kiushu Agricultural Experiment Station, at Kumamoto, Japan; and Nos. 164 and 165, which were presented to the station by Mr. McQuaid, of the Kona Developing Company, Island of Hawaii, who secured them from Japanese farmer at south Kona, were tested in comparison with the two Japan varieties previously grown (Nos. 144 and 153). (See Plate V). All the varieties made a good growth and are considered promising. Of these, variety No. 164 has given splendid results both in submerged and upland culture, and a half acre is being grown in two widely separated localities this year. Variety No. 165 is also a heavy yielder, doing well under both dry and wet land culture, but its opaque kernel, which limits its use to the "Mochi-gomi" of the Japanese, and "No-mai," or cake flour, of the Chinese, will prevent its extensive planting, except possibly as a stock feed or for the manufacture of "Miso."

The following milling test was made by the City Mill Company at Honolulu:

	Prime Rice	Broken Rice.
	Per Cent.	*Per Cent.*
Rice No. 19	62	4.0
Rice No, 39	61	3.0
Rice No. 65	67	1.0
Rice No. 73	67	1.0

Better results would perhaps be obtained on large quantities of rice.

The upland rices, Nos. 65, 68, and 154a, yielded slightly less during the past year than the year previous, but a good quality of stock seed was secured. Nos. 67 and 154b have been discarded as inferior to the other varieties.

Pure strains of stock seed of Nos. 19, 39, 65, 68, 73, 153 and 154a, are now available for distribution. (See Pl. V).

FERTILIZER EXPERIMENTS.

EXPERIMENT I. RESIDUAL FERTILIZER EXPERIMENT.

The object of this experiment was to determine the residual value upon the spring crop of Japan and Gold Seed rice, of fertilizers that were applied to the previous fall crop. The experiment is a continuation of "fertilizers experiment III" (1907), which is reported in detail in the first report of rice investigations.[a]

[a] Hawaii Sta. Rpt 1907, p. 81.

PLATE V. Fig. 1. Relative growth from equal amounts sulphate of ammonia (on left) nitate of soda (on right.)

Fig. 2. Harvesting salt marsh rice for hay.

Owing to the depredations of rice birds upon the late maturing Gold Seed of the 1907 direct fertilization experiment, no comparative data are available for the corresponding variety in the residual experiment herein reported.

The following table gives the results of this experiment:

Relative residual value of the various commercial forms of fertilizers, on rice, paddy produced by 100 clumps of rice. (a)

Plat number.	Fertilizer applied.	Amount per acre.	Equivalent.	Check (untreated). Average of 10 plats.		Fertilized before planting.		Limed (750 lbs.) and fertilized before planting.		Fertilized after plants were three-fourths grown.	
				Japan Seed.	Gold Seed.	Japan Seed.	Gold Seed.	Japan Seed.	Gold Seed.	Japan Seed.	Gold Seed.
		Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
1	Nitrate of soda	266	40 N			2.4	(*b*)	2.7	4.4	2.5	(*b*)
2	Sulphate of ammonia	200	40 N			2.5	3.8	2.5	4.0	3.3	4.6
3	Sulphate of potash	95	45 K_2O			2.3	2.7	2.4	3.3	3.1	4.5
4	Sulphate of potash and magnesia	180	45 K_2O 61 $MgSO_4$			2.3	2.7	2.4	3.2	3.4	4.7
5	Acid phosphate	125	25 P_2O_5			2.4	2.6	2.6	3.4	3.1	5.1
6	Reverted phosphate	156	25 P_2O_5			2.2	3.2	3.5	3.7	3.1	4.5
7	Thomas slag phosphate	156	25 P_2O_5 62 CaO	2.3	2.6	2.4	3.0	2.5	3.6	3.0	4.3
8	Complete fertilizer A (nitrate of soda, acid phosphate, and sulphate of potash)	350	28 N 17.5 P_2O_5 31.5 K_2O			2.3	3.7	2.4	3.8	2.6	4.5
9	Complete fertilizer B (sulphate of ammonia, fish guano, reverted phosphate, and sulphate of potash)	350	28 N 17.5 P_2O_5 31.5 K_2O			2.2	3.7	2.3	4.0	2.5	4.2
10	Complete fertilizer C (nitrate of soda, Thomas slag phosphate, and sulphate of potash and magnesia	350	28 N 17.5 P_2O_5 31.5 K_2O			2.3	3.0	2.5	3.0	2.6	4.0

(*a*) Results from materials containing a single fertilizer constituent not comparable with the complete fertilizers which contain only 70 per cent of the constituents applied singly, although the preparations are the same.
(*b*) Weight lost.

SUMMARY.

From the data given in the preceeding (allowing 0.3 pound for experimental error), it would appear that the Japan Seed received no residual value from any of the fertilizing materials when applied to the previous crop before planting; but that the Gold Seed was benefited to the extent of 34 per cent increase from the residual effects of sulphate of ammonia, 11 per cent from the reverted phosphate, 0.3 per cent from the Thomas slag phosphate, 30 per cent each from complete fertilizers A and B, and 0.3 per cent from complete fertilizer C.

When limed with 750 pounds of slacked lime in addition to fertilizing before planting, the Japan Seed failed to show any increase in yield, due to any of the treatments. On the other hand, Gold Seed appears to show decidedly increased yields under like conditions. This may be due to the more vigorous and longer period of growth characteristic of the latter variety, and would indicate that liming may prove beneficial when applied to a neutral soil, provided it is applied sufficiently in advance of planting the crop.[a]

The largest residual value was received by both varieties of rice when the fertilizers were applied to the previous crop when three-fourths grown. Thus allowing 13 per cent for experimental error, we get the following results:

Residual value of fertilizer materials when applied to the previous crop three-fourths grown.

Treatment.	Increase over untreated plats.	
	Japan Seed Paddy.	Gold Seed Paddy.
	Per Cent.	*Per Cent.*
Nitrate of Soda	00	* (*a*)
Sulphate of Ammonia	30	63
Sulphate of Potash	21	60
Sulphate of Potash and Magnesia	34	67
Acid Phosphate	21	83
Reverted Phosphate	21	60
Thomas slag Phosphate	17	52
Complete Fertilizer A*b*	00	60
Complete Fertilizer B*b*	00	48
Complete Fertilizer C*b*	00	40

* *a* Weight lost.

b Contains only 70 per cent of the constituents applied singly and therefore not comparable.

[a] The application of lime to the previous crops lowers the yield in every instance. See Experiment III, Hawaii Sta. Rpt. 1907, p. 81.

Experiment II. Residual Fertilizer Experiment (B).

This experiment is a continuation of pot fertilizer experiment II of the 1907 series.[a]

After lying fallow in the pots for six months, the originally fertilized soil was submerged under several inches of water, as is the custom in field culture. When thoroughly softened the mud was stirred to a depth of 4 inches and then left to settle.

Five 15-day-old seedlings of selected Japan Seed rice No. 153 were transplanted into each pot, three pots forming a series.

The plants grew well, and the paddy of all the series was harvested at one time, even though a few days difference in maturity was apparent in some of the series.

The residual value of the various commercial fertilizer materials as shown by pot cultures when the fertilizers were applied to the previous crop at the rate of fifty pounds per acre of each element, is shown below:

Residual effect of fertilizers in pot cultures with Japan rice.

Series.	Treatment.	Yield of paddy.	Series.	Treatment.	Yield of paddy.
		Grains.			*Grains.*
I	Check	5.1	X	Sulphate of ammonia and acid phosphate	5.8
II	Nitrate of soda and sulphate of potash	5.8	XI	Sulphate of ammonia and Thomas slag phosphate.	6.5
III	Nitrate of soda and muriate of potash	5.9	XII	Fish guano and acid phosphate	5.2
IV	Sulphate of ammonia and sulphate of potash	7.0	XIII	Fish guano and Thomas slag phosphate	5.3
V	Sulphate of ammonia and muriate of potash	5.6	XIV	Acid phosphate and sulphate of potash	5.7
VI	Fish guano and sulphate of potash	7.3	XV	Acid Phosphate and muriate of potash	*a*
VII	Fish guano and muriate of potash	5.8	XVI	Thomas slag phosphate and sulphate of potash.	5.4
VIII	Nitrate of soda and acid phosphate	6.0	XVII	Thomas slag phosphate and muriate of potash	*a*
IX	Nitrate of soda and Thomas slag phosphate	5.9	XVIII	Equivalent proportion of each element in each of the forms represented above	*b*

(*a*) Weight in doubt. (*b*) Plants failed to mature.

SUMMARY.

In the 1907 direct fertilizer experiment, one pot of each series had been limed and one drained, while the third received no other treatment than the application of fertilizer. In the direct fertilizer experiment, the limed pots in every series showed some

a Hawaii Sta. Rpt. 1907, p. 80.

depression, varying from 14 to 40 per cent in the decreased yield of straw and paddy. In the residual experiment no such depression was noticeable due to liming, the lime evidently having been neutralized in the meantime. All the pots of a series showed uniformity in growth. It could not be noticed that draining the pots exerted any influence upon the yield. The loss of fertility due to leaching was apparently insufficient to influence the growth.

The results of the experiment seem to indicate that the largest residual value was derived from the fish guano and sulphate of potash (Series IV). The next best result seemed to have been obtained from sulphate of ammonia and Thomas slag phosphate (Series XI), nitrate of soda and acid phosphate gave better results than sulphate of ammonia and acid phosphate (Series VIII), nitrate of soda and muriate of potash, and nitrate of soda and Thomas slag phosphate, gave equal results (Series III and IX). It is difficult to understand why the fish guano in combination with acid phosphate and Thomas slag should have given the poorest results in the whole experiment, while the fish guano and phosphate gave good results in other combinations.

From the above experiment, it would appear that considerable residual value may result from the application of moderate quantities of some of the commercial fertilizer materials, even when applied to the previous crop before planting.

In residual experiment the quick maturing Japan Seed derived little or no benefit when the preceding crop was fertilized before planting, but the more vigorous and slowly maturing Gold Seed showed increased yields up to 34 per cent under the same treatment. However, when the previous crop was fertilized after the crop was three-fourths grown, material benefit was derived by both the Japan Seed and Gold Seed, the strong growing Gold Seed receiving the greatest benefit.

So far as the two experiments are comparable, there is agreement in the general principle involved, i. e., that chemical fertilizers may exert influence upon succeeding crops and that such influence depends upon the amount and period of its application. It may further be concluded :

(1). That nitrogen in sulphate of ammonia, and in the organic form; phosphoric acid in the water soluble, reverted and tetra calcic forms; and potash as a sulphate and a muriate, may exert residual value when applied in sufficient quantities before planting the preceeding crop, the stronger and more vigorous growing variety deriving the greater benefit.

(2). That the same fertilizers, in like quantity, applied to the crop first preceding when well advanced in growth, will exert a considerably greater residual benefit upon the succeeding crop than if applied before planting.

It has already been determined in a former experiment, that, with the single exception of nitrate of soda, fertilizer materials

exert the greatest benefit to the immediate crop when applied before planting.

Thus may we conclude that, while fertilization before planting benefits the immediate crop most, the greatest residual benefit is derived from fertilizers applied to the previous crop when well advanced in growth.

Thus it will be seen that each method has an advantage as well as a disadvantage. The relative economy of the two methods of fertilization has not yet been determined, but from the experimental data thus far accumulated, and from the well-known fact that the spring crop is naturally the lighter where two crops are grown annually, and responds most to fertilization, it would seem that liberal applications of fertilizers applied to the spring crop, before planting, would produce the maximum spring yield and carry over sufficient residue to give a maximum fall crop without additional fertilizer, or, if a stimulant should be needed as the fall crop advances, a light application of sulphate of ammonia or nitrate of soda might be applied at the drying off period preceding the flowering stage. An experiment is now under way to determine these points.

Experiment iii. Direct Fertilizer Experiments.

Three tests to compare the relative value of several commercial forms of nitrogen as fertilizers for the rice crop were made during different seasons of the year.

The subjoined table gives the results of the first series of these tests together with the results obtained from green manure, stable manure, and the complete rice fertilizer recently formulated by the station.

This series of tests was made under identical season, soil, and cultural conditions, so that the results are comparable and represent the yield of paddy from 100 clumps of rice.

Relative value of various forms of nitrogen for rice.

Plat Number	Fertilizer applied.	Amount per Acre	Height of plants at maturity.	Green weight whole plants	No. of culms per clump of five plants.	Weight of paddy	Date of maturity.
		Pounds.	*Inches.*	*Pounds.*		*Pounds.*	
I	Check (no fertilizer).....	.....	32-35	45	15-20	5.3	July 20
II	Complete fertilizer *a*	350	38-40	48	20-22	7.1	July 22
III	Stable manure.....	5000	40-45	55	21-23	6.8	July 25
IV	Complete fertilizer *b*	350	40-43	51	20-25	7.9	July 20
V	Check.....	.....	34-35	46	17-20	5.7	July 22
VI	Green manure.....	20000	40-48	60	20-25	5.9	July 30
VII	Sulphate of Ammonia	200	44-48	64	25-27	8.1	July 25
VIII	Lime Nitrogen..	266	38-42	50	22-24	6.7	July 25
IX	Check.....	.....	30-34	44	16-18	5.2	July 20
X	Nitrate of soda.....	266	35-38	47	20-22	5.9	July 28

a. Applied when the crop was two-thirds grown.
b. Applied before planting.
Balance of fertilizers, except stable manure and green manure, applied to crop when two-thirds grown.

SUMMARY.

In the test of the nitrogenous fertilizers, nitrogen was applied at the rate of 40 pounds per acre, when the crop was one-half to two-thirds grown, the materials being applied broadcast upon the receding flood water which precedes the drying off period, a short time before the rice comes into bloom. (See Pl. IV).

The increase in yields of paddy over untreated plats was as follows: With sulphate of ammonia, 50 per cent; lime nitrogen, 24 per cent; nitrate of soda, 9.2 per cent.

The green manure (legumes and weeds) yielded only 9 per cent increase in paddy, but a large increase in straw, the small yield of paddy being due to an excessive rankness of growth, in which the seed set poorly. The green manure was applied at the estimatel rate of 20,000 pounds per acre, and was worked into the submerged soil just previous to planting, as is the custom in Oriental countries, and it is probable that the material was applied at too short an interval before planting, or in quantities excessive for the amounts of mineral matter available.

A further observation illustrates the danger of excessive green manuring.

The green manure plat showed rankness in growth especially along the outer rows, adjoining the dikes where an extra amount of vegetation had unavoidably accumulated.

The first and outer row failed to set fruit, although it flowered and tillered freely; the second row showed less rankness, and seeded fairly well. Irregular ripening characterized the fruiting panicles; rows 3 to 5 were fairly uniform in height, fresh weight, yield of paddy, and maturity.

Compared with the results obtained from sulphate of ammonia, the green manure produced plants of about equal height, but less tillering, slower maturity and less uniformity. The 5,000 pounds stable manure per acre gave 26 per cent increase in yield of paddy. The complete fertilizer yielded 31 per cent increase when applied to the crop two-thirds grown, and 46 per cent when applied before planting. This latter fertilizer supplied 17½ pounds of nitrogen per acre.

Experiments iv and v.

In experiments 4 and 5 the comparative value of different forms of nitrogen for Japan and Hawaiian Gold Seed rice and for different varieties of Japan rice was tested. In each case the yield of 100 clumps of rice was taken. The acompanying tables give the results of the experiments:

Relative value of commercial forms of nitrogen as fertilizers when applied to Japan Seed and Hawaiian Gold Seed rice.

	Amount per acre.	Japan Seed.		Hawaiian Gold Seed.	
		Yield of paddy.	Increase.	Yield of paddy.	Increase.
	Pounds.	*Pounds.*	*Per cent.*	*Pounds.*	*Per cent.*
Check (average of 3 plats)	.....	2.6	.....	3.1	.....
Nitrate of soda	266	2.8	7.6	3.3	6.4
Sulphate of ammonia	200	4.1	57.6	5.2	67.7
Lime nitrogen	266	3.0	15.8	4.1	32.2

Relative value of different commercial forms of nitrogen as fertilizers when applied to various types of Japan rice at an early stage of growth.

Variety No.	Fertilizers applied (equivalent of 40 pounds nitrogen).						
	Check. (average of 2 plats).	Sulphate of ammonia.		Nitrate of soda.		Lime-nitrogen.	
		Yield of paddy.	Increase overcheck.	Yield of paddy.	Increase overcheck	Yield of paddy.	Increase overcheck.
	Pounds.	*Pounds.*	*Per cent.*	*Pounds.*	*Per cent.*	*Pounds.*	*Per cent.*
144	2.15	2.94	37	2.30	7	2.64	22
161	4.06	6.00	48	4.54	12	5.30	31
163	4.50	6.47	44	5.35	19	5.80	28
165	5.20	7.33	41	5.93	14	6.62	28

In both these experiments, the sulphate of ammonia proved the most beneficial, lime nitrogen second, and nitrate of soda third. These results are in agreement with the former test.

In experiment 4, the Japan and Gold Seed were grown under identical conditions, but the Japan Seed matured in 110 days while the Gold Seed matured in 140 days. This longer period of growth after fertilization evidently acted favorably in the case of the sulphate of ammonia and the lime nitrogen, but made little or no difference in the case of the nitrate of soda.

Thus it would appear that the maximum benefit from nitrate of soda may be secured from a comparatively late application, while the sulphate of ammonia, and especially the lime nitrogen, require a considerably longer period in which to exert their maximum power. Furthermore, it is evident that when applied in large quantities, either early or late, but a small percentage of the nitrogen in nitrate of soda is taken up by the plant.

Fertilizer Experiments on Dryland Rice.

The fertilizer tests upon dry-land rice resulted in indefinite results as regards the yield of paddy, owing to the unusually dry season. However, on both the silty loam of the station grounds and the gravelly loam of the rice trial grounds the muriate of potash, sulphate of ammonia, and nitrate of soda increased the yield of straw in the order named. The other constituents applied in the same forms and amounts as shown in table on page 71, appeared to exert no influence.

Co-operative Experiments With a Complete Fertilizer

Three cooperative tests with a complete fertilizer were undertaken on three separate plantations.

The fertilizer was of the following composition:

5 per cent nitrogen—2 per cent as organic (fish guano and dried blood), 3 per cent as sulphate of ammonia.

9 per cent phosphoric acid—4 per cent as acid phosphate, 5 per cent as reverted phosphate.

12 per cent potash as sulphate of potash.

The fertilizer was applied at the rate of approximately 350 pounds per acre. This is equivalent to 17.5 pounds nitrogen, 31.5 pounds phosphoric acid, and 4.2 pounds potash per acre. The cost of this mixture in the Honolulu market is about $50 per ton, hence the cost of fertilizing, including transportation and application, approximates $10 per acre.

The results from these experiments were as follows:

At Punaluu Plantation, Oahu, which has been continuously under rice since 1872, the average yield on 37 acres has been less than 74,000 pounds paddy per spring crop. Five tons of the above formula was applied to the 37 acres, and the increased yield of paddy, covering the whole area, was estimated at 35 per cent over the average of former crops.

Valuing the paddy at $2.25 per hundred pounds and making a liberal allowance for the cost of fertilization, a net profit of $6 per acre was obtained upon the first crop. As the fertilizer was applied to the crop when it was two-thirds grown, a considerable residue should be conveyed to the subsequent crop.[a]

In a second experiment adjoining the rice trial grounds at Waikiki, a one-year fallow paddy field was set to Hawaiian Gold Seed on March 2. On May 1, the complete fertilizer was applied to half the field at the rate of 350 pounds per acre. The crop was harvested the latter part of June with the following results: Unfertilized, 2,950 pounds paddy per acre; fertilized, 4,100 pounds paddy per acre.

[a] For former experiments conducted on this plantation, see Experiments V, VI, VII, Hawaii Sta. Rpt. 1907.

This gives an increase in yield of 39 per cent, which is equivalent to a net profit of $15 per acre after deducting $10 for fertilization.

In a supplementary test adjoining the above experiment, 200 pounds sulphate of ammonia (40 pounds nitrogen) gave an increased yield of 50 per cent over the unfertilized plats, an increase of 5 per cent over the plat receiving complete fertilizer. From this we may conclude that a higher percentage of nitrogen in the complete fertilizer would have yielded better results.

A third cooperative experiment yas conducted at Palama Plantation near Honolulu. The paddy field used had been cropped for twenty years and represented the poorer "kula" lands (uplands immediately bordering the better lowlands). The average yield was said to be less than 1,800 pounds paddy per acre. The complete fertilizer was applied to the crop shortly after planting, at the rate of between 350 and 400 pounds per acre. The estimated increase in yield was between 75 to 100 per cent over the unfertilized field. Owing to the crop being cut before a representative of the station arrived, no actual weighings could be made. The estimate was made by the planter. Based upon the results of this experiment, the station was called upon to plan a scheme for the systematic fertilization of the whole plantation.

UPLAND RICE AS A HAY AND GRAIN CROP.

The experiments with upland rice grown under minimum amounts of irrigation water are now in their second year and have given results which are summarized below.

Of the eight or ten varieties of upland rice entering into the first comparative tests, all have been eliminated except variety No. 68 (S. P. I. Inv. No. 17917), a dwarf, bearded rice from northern China, which matures in 100 to 115 days; variety No. 65 (S. P. I. Inv. No. 17144), a strong growing smooth hulled, beardless type, of Egyptian origin, extensively known in Louisiana as "Bull Rice"; No. 154a, a Porto Rico upland rice resembling the Gold Seed; and possibly No. 19 (S. P. I. Inv. No. 12508), the Ceylon rice described under variety tests, and which promises well under ordinary submerged culture.

A spring, summer, and fall planting gave the following mean results:

Summary of mean results obtained with a minimum amount of water upon upland rice.

Variety.	Method of planting.	Length of growing season.	Total water received. (irrigation and rainfall)	Yield of paddy.	Yield of hay (approximate)
		Days.	*Acre Inches.*	*Pounds.*	*Pounds.*
No. 19 (S. P. I. Inv. No. 12508)	Drilled	190	47.0	.....(*a*)	10,000
No. 65 (S. P. I. Inv. 17144)	"	143	30.6	5,014	9,926
No. 68 (S. P. I. Inv. 17917)	"	109	23.5	2,080	5,920
No. 68 (S. P. I. Inv. 17917)	Aftermath	34	5.9	.....(*b*)	2,240
No. 154 (*a*)	Drilled	145	30.0	.....(*b*)	5,000

In the above data, the rainfall is included with the irrigation water, which was applied bi-weekly at the rate of approximately $2\frac{1}{2}$ acre inches per application. This is equivalent to about 0.2 inches per day during the growing period.

When double the above amount of water was used, i. e., $2\frac{1}{2}$ acre-inches weekly, the yield of hay was increased from 20 per cent in the case of varieties Nos. 65 and 68, up to 50 per cent with variety No. 19; but the grain was not increased proportionately.

When grown under submerged conditions, the yields of both paddy and hay failed to exceed those receiving weekly irrigations of $2\frac{1}{2}$ acre-inches. With half the minimum amount of irrigation represented in the foregoing table, i. e., $2\frac{1}{2}$ acre-inches once in four weeks, all the varieties suffered severely and failed to make a crop.

From the above we may conclude that $2\frac{1}{2}$ acre-inches of water every two weeks during the growing season is the minimum moisture which will insure a paying crop, and the $2\frac{1}{2}$ acre-inches of water weekly is near the optimum.

Two factors of equal importance in insuring a crop under a minimum water supply are deep and thorough tillage and light seeding. In a well tilled field, drilled at the rate of 60 pounds seed per acre, without irrigation, all the varieties failed to reach the fruiting stage under 10 inches of rainfall. However, when seedlings of the quick maturing variety No. 68 were thinned so as to stand 6 to 12 inches apart, in drills 8 inches apart, the plants tillered well and produced perfect seeds. Where the plants stood eight to the running foot, very little tillering occurred and only an occasional glume bore sparingly of seed. With sixteen seedlings to the running foot of drill (approximate stand from 60 pounds seed per acre), the plants entirely failed to set seed.

(*a*) Failed to set seed well.
(*b*) Not estimated.

PLATE VI. Fig. 1. Chinese mat rush, *(Cyperus tegetiformis)* five months from planting

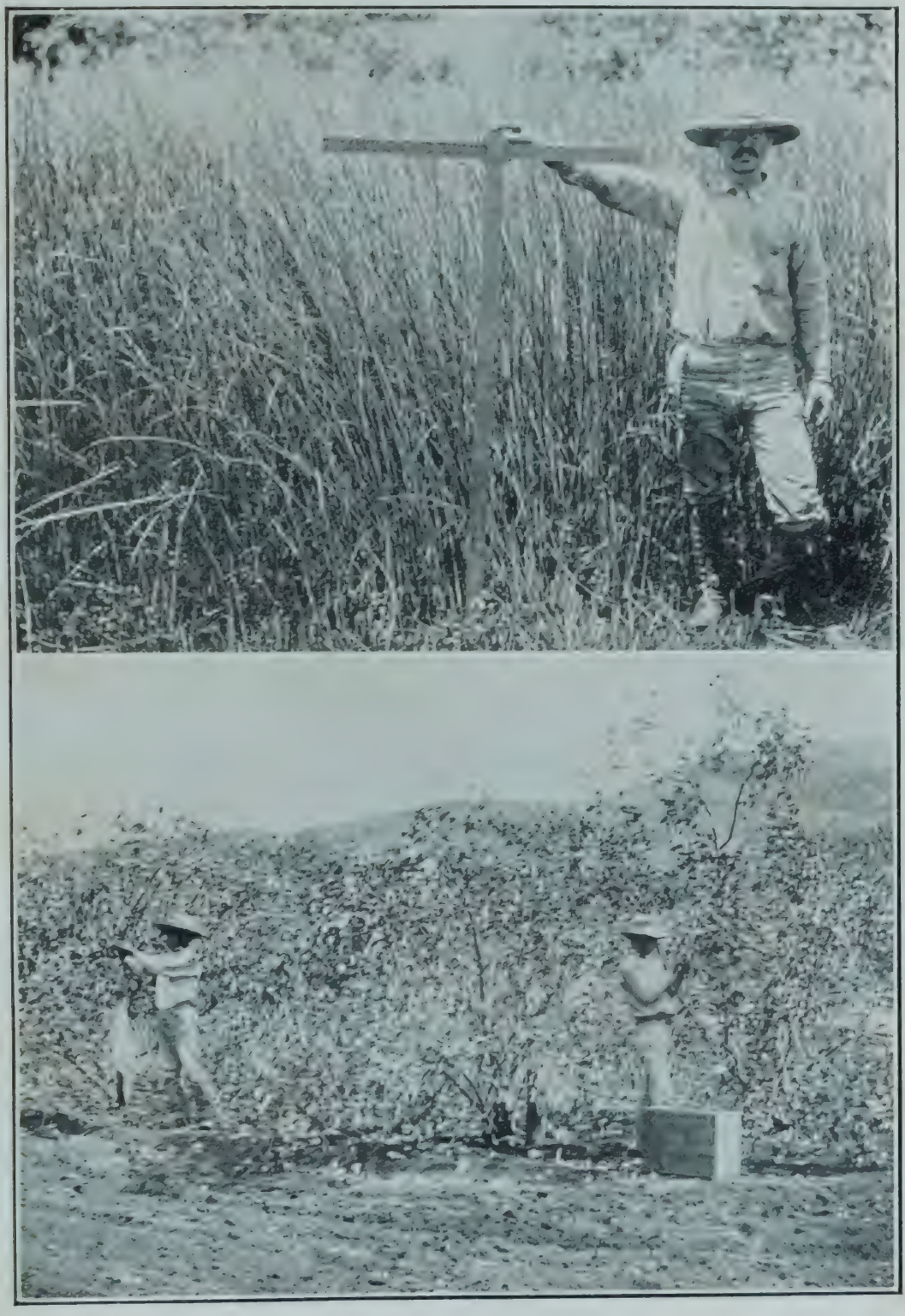


Fig. 2. Caravonica tree cotton at Hawaii Experiment Station.

Where the soil was poorly prepared, the plants made a much poorer growth than where the tilth was good. Under good tillage the development of the root system of one plant was equal to that of four to six plants in poorly prepared soil. The same relative development was true of plants set well apart and those that were crowded.

From this we may conclude that it is essential that the seed bed be thoroughly prepared and that the seed be sown thinly. The importance of this becomes greater as the supply of moisture becomes smaller.

Chemical analysis of the different varieties of rice entering into these experiments will be found in the report of the assistant chemist.

SALT-MARSH RICE AS HAY.

The price of imported cereal hays, exceeds $20 per ton, and the total importation is 10,000 tons, valued at a quarter of a million dollars annually. This fact has induced the station to devote some attention to developing a home-grown substitute. Much hope is entertained for upland rice in this regard. It has been further suggested that the inferior types of rices, such as the salt-resisting marsh varieties, which are now much used as adulterants in the standard sorts, might be utilized as a cured fodder for horses and cattle.

The following data have been obtained from an experimental harvest. Early in the spring an acre of growing marsh rice of average stand and quality was secured, adjoining the trial grounds.

The grain was in the milk stage May 20, when the flood water was drained from the field. On May 22 the ground was sufficiently firm to bear the weight of a man and the first cutting was made. Four days later most of the grain had entered the dough stage and another cutting was made. By May 30, most of the grain began to harden and the last harvest was made.

Calculated to acre yields, the following results were obtained:

Total green weight	14,212
Total air cured matter as hay	5,852
Total as cured paddy	2,842

At $25.00 per ton, the gross value would be $73.15 per acre as cured hay; and rating the paddy at $2 per 100 pounds, (a high price for this variety), its value would be $56.84 per acre.

The cost of harvesting for hay or grain would be about equal. The cost of curing and baling as hay should not exceed the cost of threshing and bagging the paddy. No special difficulty was experienced in securing a well cured hay, although the grain was found to shatter badly in the lot harvested when fully ripe. (See Pl. V).

Extensive feeding experiments have not yet been undertaken. However, it has been found that some horses feed greedily upon the well cured hay from the start, while others merely nibble the grain. The writer has fed a half ton to a horse and a cow with success, and the Chinese rice growers feed it almost exclusively to their horses; frequently they feed the straw alone.

Estimating the salt-marsh lands of Oahu now devoted to this type of rice at 1,000 acres, and allowing $10 increase revenue per acre by cutting the crop as hay, $10,000 per crop or $20,000 per annum could be added to the profits of the rice growers. A number of practical feeding tests are to be undertaken this fall.

CHINESE AND JAPANESE MAT RUSH EXPERIMENTS.

The species represented in these experiments are *Cyperus tegetiformis,* the Chinese mat rush (Seaside grass, Pl. VI), and *Juncus effusus,* the Bingo-i mat rush of Japan. Three plantings and three harvests have thus far been completed at the rice trial grounds near Honolulu, and a first planting at Kailua, on the windward side of Oahu. Each succeeding crop has been better than the previous one and the following results represent our best yields. In three average cuttings of 100 square feet each the Chinese mat rush yielded cured reeds at the rate of:

	Pounds per Acre.
60 inches and over	8,712
48 to 60 inches	5,762
36 to 48 inches	5,227

It required between 6 and 7 months for the spring crop to mature from direct planting. The fall crop matures in about 5 months when grown from rattoons. This second crop does not attain the length of the planted crop but the stand is more dense. The crop at Kailua is not yet mature, but promises well.

Sample reeds of the Chinese rush have been forwarded to a matting factory and reports as to quality are expected shortly. The Japanese mat rush has greatly improved during the past year and presents a fine appearance at this writing. A large stock of plants have been propagated and it is planned to set out several acres during the coming fall.

The greatest obstacle in the way of making the growing of the Chinese rush a profitable crop in Hawaii appears to be the large expense attached to preparing the rushes for market. Each reed requires to be split lengthwise before curing.

COTTON EXPERIMENTS.

Stray cotton plants appear in many parts of the Hawaiian group. As long ago as 1856, F. A. Oudinot reported[a] upon a

[a] Trans. Roy. Hawaii Agr. Soc., 2. (1860), No. 3, pp. 104-106.

cotton tree growing at Lahaina, Maui, which was said to be fifteen years old at that time. The variety is stated to be the Sea Island. Several attempts have been made to grow cotton upon a commercial scale, but the industry was never developed. Renewed interest at this time is very pronounced. A first variety test of cotton was made by the station in 1905-6. The quality of several of the varieties was favorably reported upon by the fiber experts of the U. S. Department of Agriculture and also by manufacturers.

A number of three-year-old pants of the Caravonica type are still growing on the station grounds and bear a fair quality of cotton. A recent experimental picking yielded 15 pounds seed cotton from a single plant. The plants bear continuously throughout the year. Some of the plants are being cut back to determine the influence of pruning. The kidney, silk, and wool Caravonica plants at the station are now three years old. (See Pl. VI). The plants will average at least 5 pounds per tree, and two such pickings can be made annually.

Beginning in March of the present year, a variety test was undertaken with two strains of Sea Island, two types of Caravonica, and a Chinese type of upland cotton. At the end of the fiscal year, June 30, the Sea Island was well in bloom and all the varieties were doing finely.

SOY BEANS.

The soy bean possesses many advantages as a green manuring or rotation crop. Early in the present year, three varieties of soy beans were obtained through the Bureau of Plant Industry. These were designated at Nos. 20797, 20798, and 21080. All were supposedly tall-growing varieties, which had been introduced into the Southern States as fodder and green manuring crops. Seed of two other varieties were donated by the Hawaiian Yamajo Soy Company of Honolulu. One of these, a green seeded type, has been grown in the Kona district of Hawaii for some years; the other, a yellow seeded variety, was imported direct from Japan. The seed of both of these varieties is used in the manufacture of the Japanese food product, "Miso," and other preparations.

All the varieties were sown on March 12. Variety No. 21080, which proved to be a dwarf type suitable for shelled beans, and the two Japan sorts matured in about 100 days from planting, (see Pl. VII, fig. 2). Planted in drills 12 by 18 inches apart, the following yields of shelled beans per acre were obtained:

Variety No. 21080, 600 pounds of shelled beans per acre; imported Japan, 800 pounds; and Kona seed, 1,060 pounds.

The plants of the above varieties are very dwarf, average less than 12 inches in height, and are upright in growth. It seems likely that closer planting, say 6 inches apart in the drill, will give material increase in yields. The average price in the Hono-

lulu market is $3 per hundred pounds. About 500 tons of the beans are imported from Japan annually, and the demand is said to be on the increase.

It would appear that this could be made a profitable crop for the small farmer. The plant requires little moisture, but responds well to thorough hand tillage, which permits of close planting. Careful selections have been made and it is hoped that more prolific strains will be developed.

The tall-growing varieties are making a vigorous growth and have attained a height of from 10 to 30 inches. (See Pl. VII, fig. 1), The plants appear to be very irregular in size and maturity, as if the types had not been established. Two hundred pods have been counted on single plants, while others have not come into flower. All the varieties appear to be well supplied with root nodules.

PEANUTS.

Variety and cultural tests of the following varieties of peanuts are now under way: Spanish, Bunch Jumbo, Running Jumbo, and Virginia Running. Three types of soil at different elevations, and with varying amounts of soil moisture are being considered. Planted April 20, the varieties are making fine growth and flowering profusely June 30. The plants have made a spread of fully 4 feet.

LEGHORN WHEAT.

A small quantity of seed of the wheat, the straw of which is used in the manufacture of the Italian Leghorn hats, was received under the name "Corn, Suta Fiore."

Drilled in rows 12 inches apart on March 23, the culms attained a height of 36 to 40 inches up to June 30. The plants tiller well and appear to require about as much moisture as upland rice.

PLATE VII. Fig. 1. Plat of Soy Beans

Fig. 2. Dwarf Soy beans, used in making "Miso" and other Japanese food products.

HAWAII AGRICULTURAL EXPERIMENT STATION
E. V. WILCOX, SPECIAL AGENT IN CHARGE.

ANNUAL REPORT

OF THE

HAWAII AGRICULTURAL EXPERIMENT STATION

FOR

1909

UNDER THE SUPERVISION OF
OFFICE OF EXPERIMENT STATIONS.
U. S. DEPARTMENT OF AGRICULTURE.

HONOLULU:
PARADISE OF THE PACIFIC PRESS
1910

HAWAII AGRICULTURAL EXPERIMENT STATION, HONOLULU.

[Under the supervision of A. C. TRUE, Director of the Office of Experiment Stations, United States Department of Agriculture.]

WALTER H. EVANS, *Chief of Division of Insular Stations, Office of Experiment Stations.*

STATION STAFF:

E. V. WILCOX, *Special Agent in Charge.*
J. EDGAR HIGGINS, *Horticulturist.*
F. G. KRAUSS, *Agronomist.*
W. P. KELLEY, *Chemist.*
D. T. FULLAWAY, *Entomologist.*
ALICE R. THOMPSON, *Assistant Chemist.*
C. J. HUNN, *Assistant Horticulturist.*
Q. Q. BRADFORD, *Assistant in Agronomy.*
V. S. HOLT, *Assistant in Horticulture.*

LETTER OF TRANSMITTAL

HAWAII AGRICULTURAL EXPERIMENT STATION,
HONOLULU, HAWAII, Feb. 16, 1910.

SIR: I have the honor to transmit herewith and to recommend for publication the Annual Report of the Hawaii Agricultural Experiment Station for the fiscal year 1909.

Respectfully,

E. V. WILCOX,
Special Agent in Charge.

DR. A. C. TRUE,
Director Office of Experiment Stations,
U. S. Department of Agriculture, Washington, D. C.

Publication recommended.
A. C. TRUE, *Director.*

Publication authorized.
JAMES WILSON, *Secretary of Agriculture.*

CONTENTS.

	Page.
Summary of investigations	9
Diversified agriculture	9
Chemical investigations	10
Cotton investigations	11
Entomological investigations	12
Horticultural investigations	13
Rice investigations	14
Rubber investigations	15
Miscellaneous investigations	15
Report of the entomologist	17
General insect notes	17
Synopsis of Hawaiian Aphidae	20
Report of the horticulturist	47
Fruit marketing investigations	47
Propagation investigations	47
Citrus fruits	47
Mango propagation	50
Avocado propagation	51
Records	51
Development of experimental orchards	52
The use of hydrocyanic acid gas in orchards	53
Cover crops	53
Wind-breaks for orchards	54
Vegetables and small fruits	54
The horticultural staff	56
Miscellaneous notes	56
Report of the chemist	58
Pineapple soils	58
Rice investigations	63
Fertilizer experiment with cotton, and miscellaneous	64
Report of the agronomist	66
Rice experiments	66
Cooperative fertilizer tests	67
Testing and developing new varieties of rice	68
Cotton experiments	69
Growing cotton from cuttings	71
Budding cotton	71
General cultural notes	72
Varieties	73
Time of planting and distances to plant	74
Improving a strain	75
Miscellaneous experiments	75

ILLUSTRATIONS.

TEXT FIGURES.

		Page.
Fig. 1.	*Macrosiphum kirkaldyi*, wingless viviparous female	23
Fig. 2.	*Macrosiphum kirkaldyi*, winged viviparous female..	24
Fig. 3.	*Toxoptera caricis*, wingless viviparous female.....	32
Fig. 4.	*Toxoptera caricis*, winged viviparous female.....	33
Fig. 5.	*Aphis bambusae*, wingless viviparous female.....	36
Fig. 6.	*Aphis bambusae*, winged viviparous female.....	37
Fig. 7.	*Aphis swezeyi*, wingless viviparous female.....	38
Fig. 8.	*Aphis swezeyi*, winged viviparous female.....	40

PLATES.

Plate	I.	Bahia navel orange on common sweet orange stock	57
Plate	II.	General view of four cultivated fields.....	57
Plate	III.	Field C, showing location of trees	57
Plate	IV.	Three-year-old pruned Caravonica cottons.....	76
Plate	V.	Cotton cuttings	76
Plate	VI.	Caravonica cotton grown from cuttings.....	76
Plate	VII.	Budded cottons	76

ANNUAL REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION FOR 1909

SUMMARY OF INVESTIGATIONS

By E. V. Wilcox, *Special Agent in Charge.*

DIVERSIFIED AGRICULTURE.

During the past year gratifying success has been had in developing a substantial interest in the diversification of agriculture in the Territory. The apparent hesitation which has frequently been shown by citizens of the Territory in engaging in general lines of agriculture has evidently been due not to any doubt as to the possibility of raising a great variety of crops, but to a lack of specific experimental data as to where the best seed may be obtained, the best cultural methods for these crops, and facilities for marketing them. All of our citizens, who are most actively interested in the development of the Territory, have gladly welcomed any information or experimental data which may serve to establish, on a business foundation, any line of agricultural industry which promises commercial success. This statement is fully justified by the active interest shown in the pineapple industry, the development of rubber plantations, the rapid spread of cotton planting, the cooperation of land owners and growers in making the rice crop more profitable, and in the general activity in increasing the acreage of forage crops, garden crops, and miscellaneous fruits and crops.

The area planted to corn is being rapidly enlarged and satisfactory returns are everywhere being reported. From large areas average yields of forty bushels per acre of corn have been obtained under rainfall conditions varying from 5 to 240 inches per year, and at altitudes ranging from sea-level to 5,000 feet.

The acreage of alfalfa, sorghum, Rhodes grass, Para grass, cowpeas, jack beans, soy beans, and other forage crops is increasing at a corresponding rate.

Not only are these crops, which are regarded as the mainstay of agriculture in temperate climates, considered as worth while in themselves, but their importance in systems of rotation is being recognized, and this means that the further extension of the area devoted to miscellaneous crops will proceed more rapidly in the future than in the past.

The definite policy has been adopted of making the chief work of the members of the staff that of investigation, in order that actual contributions may be made to the sum total of agricultural science. Naturally, however, some attention must be given from time to time to miscellaneous requests for practical information from farmers. An attempt is made, however, to prevent this work from interfering too greatly with the regular lines of investigation.

CHEMICAL INVESTIGATIONS.

The chemist and assistant chemist have confined their attention during the year almost exclusively to the study of pineapple soils, research on the fertilization and nutrition of rice, and fertilizer experiments with cotton. A preliminary report on the relation of manganese to the growth of pineapples has already been published in Press Bulletin 23. It appears, from further study of pineapples, that this plant is exceedingly sensitive to soil conditions, and does not thrive satisfactorily when planted continuously on the same soil. The poor results from a one-crop system are not yet definitely explained, but are partly due to the depletion of the organic matter in the soil from this system, and the consequent packing of the lower layers of the soil. When it is remembered that these soils contain unusually large amounts of ferric hydrate, which acts very much like clay, it is easily understood that with a heavy rainfall the soil becomes saturated with water and cannot be properly aerated by superficial cultivation.

The fertilizer experiments with pineapples are not yet completed for the reason that eighteen months are required from the time of planting until the first harvest. At present, however, the growth of the plants indicates clearly that certain combinations of fertilizers are very effective, while others are prac-

tically without result. The scientific explanation of these results, and practical conclusions to be drawn from them, must be postponed until the experiment is completed.

Plans have been made for putting in two drainage experiments. There is abundant evidence that some of the poor results obtained from pineapples, in restricted areas, are due to lack of drainage. No tile drainage has hitherto been used in the islands, and it is believed to be worth while to test its efficiency under our conditions.

A considerable number of soil samples have been analyzed in order to secure data on the distribution of manganese in the pineapple fields. As indicated in the preliminary report, already referred to, black soils contain relatively high percentages of manganese and such soils have proved unsuitable for pineapple culture. It has been found that the manganese in this soil is exceedingly soluble; that in the growth of pineapples it undergoes a higher oxidation, and that this change is detrimental to plant growth. It is hoped that during the present year we may find a scientific explanation of the effect of manganese upon pineapple plants and upon the plant nutrients in the soil.

An important experiment has been undertaken with rice to determine the period of growth in which various nutrients are absorbed and their inter-relations with reference to the development of the plant. One series of cultures has already been completed, and analyses of various parts of the rice plant, at different stages of growth, are being made. The experiment will be repeated on another crop of rice in order to obtain further evidence on some of the data which have already appeared. It has been found that certain fertilizer materials affect the composition of rice as regards its nitrogen content.

The results thus far obtained from a fertilizer experiment on cotton indicate that the growth of the plants has been greatly increased by the use of phosphates.

COTTON INVESTIGATIONS.

Since the spring of 1908 considerable attention has been given to the investigation of the culture and breeding of cotton. In the experimental plats we have about 30 varieties of cotton, including Sea Island, Caravonica, Egyptian, Chinese, upland, and native cottons.

It has been found that all varieties of cotton grow here as perennials. In order to maintain a suitable form in the plants, it is desirable to pinch back the terminal buds or prune the plants. The removal of the old wood and trash helps in controlling insect troubles and makes it possible to throw the fruiting season at the desired time of the year. The operation of pruning is simple and not excessively time-consuming and can be recommended for commercial practice.

In obtaining pure strains of cotton, free from the effects of crossing, resort has been had to the use of cuttings. This has been found to be a very satisfactory way for propagating pure strains, and will be used more extensively in the future. Following upon the success had by one of the cotton growers of the Territory, a number of experiments in budding cotton have been made with satisfactory results. It seems to be no more difficult with cotton than with other plants which are commonly treated in this way.

The area planted to cotton during the past year was about 100 acres, but arrangements have already been made for planting somewhat more than a thousand acres during the coming year. All of the commercial ventures in planting cotton, thus far undertaken, have proved very encouraging. The climatic conditions, while exceedingly variable in different parts of the islands, are nearly all favorable to the growth of cotton up to at least an altitude of 800 feet, and within a range of rainfall of 20 to 100 inches.

ENTOMOLOGICAL INVESTIGATIONS.

The attention of the entomologist has been chiefly devoted to a study of cotton insects and plant lice. A bulletin on cotton insects has recently been published.[1] Leaf-eating caterpillars have been unusually injurious during the year and have made it necessary to devote some attention to these pests. Cutworms and army worms have attacked a great variety of crops, including rice and alfalfa, causing a good deal of damage, but fairly satisfactory methods of controlling these pests have been applied.

Arrangements have been made for introducing parasites of algaroba weevils, plant lice, and scale insects. The Bureau

[1] Hawaii Sta. Bul. 18.

of Entomology has already begun shipments of parasites and lady-birds for this purpose. In addition to this means of control, the Florida Experiment Station has undertaken to furnish us with cultures of parasitic fungi to aid us in keeping down scale insects and plant lice.

On account of the great prevalence of plant lice upon all sorts of cultivated and wild plants, particularly during the winter season, it has been thought desirable to make a special study of these pests. The entomologist has devoted much time to this problem. A fairly complete collection of the plant lice of the Territory has been made, and from a careful study of this collection, in connection with all available literature on the subject a synopsis of the Aphidae has been prepared in which all of the important species known to occur in Hawaii are described and details are given for their ready indentification. In this work a few new species were found and have been described.

HORTICULTURAL INVESTIGATIONS.

Much time has been given to methods of propagating citrus fruits and mangoes. The growers of these fruits have experienced considerable difficulty in successfully budding them. It appears that satisfactory results are to be obtained by adopting the ordinary method of budding citrus fruit, with an inverted "T". The lack of success in budding citrus fruit may be due to infertility of the soil, insufficient moisture, lack of vigor of the trees, and insects and fungus diseases. Attention must, therefore, be given to all of these points in order to get the best results. In this work it was found neccessary to give some attention to scale insects, aphids, cut-worms and other pests which may interfere with the success of budding. The use of kerosene emulsion was found unsatisfactory and too expensive, but far better results were obtained by fumigation. In budding mangoes the best results have been obtained from the application of the "shield" method with the inverted "T", using only well-matured wood and cutting the "T" and the "shield" very long, the former six or seven inches, and the latter, three or four inches. Gratifying success has also been obtained from inarching in the case of the mango. A series of experiments is now under way in developing a more practical method for budding the avocado. It is certain that the production of commercial quant-

ities of fine mangoes and avocados depends primarily on practical methods of budding orchards devoted to these fruits.

An elaborate system of keeping laboratory and field records for the purpose of locating trees and plants upon which experiments are made, has been devised and will tend to render the keeping of records more convenient and satisfactory.

The use of cover crops in orchards during the winter appears to be quite necessary on slopes where excessive washing of the soil would otherwise occur. For this purpose, cowpeas and jack beans have given the best results. A series of experiments with a considerable variety of garden vegetables is in progress, but the results are not yet available.

On account of numerous requests from the mainland for dried roselle, an experiment was made in drying this fruit. It was found that the dried material could not be produced profitably at the price which the mainland dealers offered for it. Our experiments indicate that 12.8 pounds of the fresh fruit are required to produce one pound of dry calyces. It would appear more profitable, therefore, to use this fruit in a fresh state for the production of jams and jellies.

RICE INVESTIGATIONS.

In a fertilizer experiment with rice it was found that 200 pounds per acre of a complete fertilizer gave practically as large yields of paddy as did greater quantities up to 800 pounds. Moreover, the results were approximately the same whether applied before the crop was planted, or when well advanced in growth. A number of cooperative fertilizer tests were made for the purpose of testing, on a commercial scale, the results already obtained on the trial grounds, and to bring greater profits, if possible, from the rice industry. These experiments were entirely satisfactory, in so far as the results from the fertilizers were concerned, but were somewhat interfered with by the unusual insect troubles to which rice was subjected during the past year. The variety of rice, referred to in previous reports as No. 19, is now firmly established and has given excellent returns wherever it has been planted. Satisfactory progress is also being made with upland rice as a hay crop.

RUBBER INVESTIGATIONS.

During the past year tapping experiments were carried out on more than 400 rubber trees for the purpose of determining the yield which may be expected from rubber, the best methods of tapping, the possibility of economically using Japanese labor for this purpose, the time of day at which tapping should be made, the effects of tapping upon rubber trees, methods of coagulating latex, and the stimulating effect of fertilizers upon the flow of latex. These experiments indicate that the Ceara rubber tree in Hawaii may be planted on a commercial scale with the assurance of reasonable profit. A bulletin, covering these investigations, is now in press.

MISCELLANEOUS INVESTIGATIONS.

During the past year some attention was given to methods of grinding algaroba pods. These constitute one of the most important forage products of Hawaii, but on account of the indigestibility of the seeds, without grinding, a large part of the protein content of the pods was lost. A number of farmers had attempted to grind the pods, but had failed on account of their sticky nature. It was found, by laboratory experiments, that by slightly moistening the cracked pods and then drying them, they could be readily ground with any form of feed mill. The importance of a special mill for grinding algaroba pods in a fresh condition, was suggested to a local inventor and machinist, who has since perfected a machine which grinds the pods in a satisfactory manner. In devising this machine, the inventor adopted some of the ideas already developed in our work and cooperated with the station to the fullest extent. The use of these machines will undoubtedly become quite general and will add greatly to the available nutritive value of the algaroba.

In the perpetual conflict with weeds it is necessary to use every possible means which is efficient in destroying them. For this reason an experiment was made in destroying various weeds by means of carbon bisulphid. It was found that herbaceous as well as shrubby weeds could readily be destroyed by this chemical. A tablespoonful of carbon bisulphid, poured upon the stem, about six inches above the ground, will cause the death of such weeds as Oi, Crotalaria, prickly pear, lantana, and

guava within a period ranging from twenty-four hours to six weeks or two months. A press bulletin on this subject has recently been published.[1]

The federal funds, available for the use of this station, were supplemented at the last session of the territorial legislature by an appropriation of $10,000 for the biennial period, and an additional sum, to be allotted by a commission, from the surplus revenues of the Income Tax. This generous appropriation by the Territory will make it possible for the station to extend its work in various directions, particularly in the study of plant diseases, forage crops, and suitable rotations. Along this line, there is already in progress, or in contemplation, rotation or intercultural experiments with rubber, pineapples, cotton, rice, taro, etc.

[1] Hawaii Sta. Press Bul. 25.

REPORT OF THE ENTOMOLOGIST

By David T. Fullaway.

GENERAL INSECT NOTES.

The year has been very interesting from an entomological standpoint in showing some long-known pests in new roles and in broadening the knowledge of our insect fauna. At the beginning of the year some attention was given to the means of combating pineapple pests, in order, primarily, to reduce the losses occasioned by these pests, but more particularly to check their spread, and this work was followed up in the spring. Dipping and fumigating suckers and the liberal application of tobacco dust to the plants kept both mealy-bug (*Pseudococcus bromeliae?*) and the scale-bug (*Diaspis bromeliae*) at a minimum. It would be well if the growers would adopt a uniform method in attempting to control these two pests.

Aside from work of a purely investigational character, numerous inquiries in regard to insect pests of agricultural crops and means of combating them have been answered by correspondence. In some instances personal inspection of the conditions was made and advice offered. The station's collection of economic insects has been maintained and much material added.

In January, 1909 the entomologist, Mr. D. L. Van Dine, secured leave of absence to visit the mainland of the United States, and on March 1st presented his resignation in order to accept a position with the United States Bureau of Entomology in the southern field crop insect and tick investigations at Dallas, Texas. The writer, who was appointed assistant entomologist at the station on August 17th, succeeded Mr. Van Dine as entomologist.

The chief investigation of the year has been of the insects affecting the cotton plant in Hawaii, the results of which are contained in Bulletin 18. This work was necessitated by the increasing interest in the possibilities of cotton growing, following the station's cultural experiments extending over three years. The cotton bollweevil (*Anthonomus grandis*), the most destruc-

tive of the insect enemies of cotton in the United States, is not found in Hawaii, and the cotton bollworm (*Heliothis obsoleta*), while here, is so heavily parasitized that it is not likely to become an important factor in cotton production. The most destructive cotton pest is probably an Indian introduction, the larva of a Tineid moth, *Gelechia gossypiella*. This bollworm in India, according to Lefroy, may cause an annual loss of $4,000,000. Here, from 5% to 50% of the crop is damaged by the worm, which attacks and destroys the young ovules, preventing the formation of bolls, or more frequently enters maturing fruit, soiling the lint and causing premature opening and rotting. The worm is attacked by a Braconid parasite (*Chelonus blackburni,*) which is more or less effective in reducing its numbers. Other pests of a more or less serious nature were found. Seedling plants are attacked by wireworms and cutworms, commonly injurious to nearly all agricultural crops. A greenfly (*Aphis gossypii*) intermittently attacks the plants and at times is very destructive. It is controlled by spraying and by predaceous enemies (Coccinellids), of which there are many introduced species. The Japanese beetle (*Adoretus tenuimaculatus*) at times attacks the foliage but does not appear to be a serious pest. Two virulent Coccid species, *Pseudococcus virgatus* and *P. filamentosus,* are at times pests of cotton and greatly injure the plants. They are being constantly held in check by predaceous enemies (Coccinellids), but can nearly always be found in the cotton field doing considerable damage. There are many minor pests, the injury from which is more or less negligible, as *Archips postvittanus* and *Amorbia emigratella,* Tortricid moths whose larvae fold the leaves, a species of Thrips injuring the buds, and a species of Tetranychus (red spider) on the foliage. The employment of artificial remedies has been advised in some cases, but on the whole, or on a large scale, is considered impractical. As stated, many insects are kept in check and their injuries greatly lightened by natural enemies. The introduction of other parasites and predators is recommended, as it is believed that much may be hoped from them.

The winter and spring were marked by excessive outbreaks of cutworms. Three species were especially bad, *Agrotis ypsilon, Heliophila unipuncta,* and *Spodoptera mauritia.* For the first time in the history of rice cultivation in the islands this cereal was attacked by *H. unipuncta.* From all the rice-

producing sections of the islands the reports indicated serious losses due to the ravages of *H. unipuncta* larvæ. Early fruiting and late maturing crops escaped, but the bulk of the rice, maturing in the latter part of May, was very badly affected. In the early part of June the entomologist visited most of the rice fields on Oahu, and while some seemed to have suffered less than others, the presence of the worm, to some extent, was established in all. At two places on Kauai, and at Kalihi, Punaluu, Haula, and Kailua on Oahu, the damage was very severe, amounting to from 10% to 60% of the crop.

Another insect of economic importance, a Tortricid moth close to *Archips* [1] (there are undoubtedly several species involved, one being *A. postvittanus,* which, however, is parasitized in the egg-stage), is increasing enormously and gives promise of being a serious pest of fruit. It attacks a great variety of soft and succulent fruits—citrus, alligator pear, guava, passion flower vine, tomato, and still others. Of these, only the citrus, alligator pear, and tomato are fruits cultivated for the market, and none is grown in a large way. If citrus culture is undertaken on an extensive scale, this pest must be taken into account, as along with other enemies of citrus fruits, the damage to the crop will be very heavy. Spraying with arsenate of lead was recommended and used with effect.

Some attention was given to beekeeping, and it was proposed to investigate the possibility of increasing the production of wax by new methods of manipulation. Suitable arrangements for this work have not yet been made.

The introduction of parasites of the beanweevils, of which several species are serious pests, attacking the pods of *Prosopis juliflora* and other leguminous plants which are used chiefly as animal fodders, has been undertaken and from the two or three shipments of parasites already received a large Braconid (*Heterospilus* sp.) has been bred in numbers and liberated. Other shipments of parasites are expected and much is hoped from them. These parasites were received from Texas, through the cooperation of the United States Bureau of Entomology, and the station is especially indebted to Dr. W. D. Hunter, in

---

1 Note. This moth has been described by A. Busck in Proc. Ent. Soc. Wash., vol. XI, p. 201 (1909), from specimens sent from here, as *Amorbia emigratella*, and is supposed to be a recent immigrant from Mexico.

charge of the southern field crop insect and tick investigations of the bureau, for his able assistance and great personal interest in an effort to introduce insects which may be of great benefit to the agricultural industries of the islands. For this work, an insect-proof house was built in which the parasites can be safely handled. It is desired later to introduce parasites of other insect pests, especially aphids and coccids. Cultures of entomophagous fungi have also been received from Florida, through the courtesy of Prof. P. H. Rolfs, Director of the Florida Agricultural Experiment Station, and will be tried on our destructive Coccidæ in the fall.

After the first blossoming of the algaroba, numerous reports were received at the station of the destructive work of a caterpillar on the algaroba blossoms. For several years the larva of a Phycitid moth, *Cryptoblabes aliena,* has been known to affect the blossoms of the keawe, but it was not believed to be especially destructive. An investigation showed that there were two distinct caterpillars working on the blossoms, the Cryptoblabes larva and the caterpillar of a moth close to Archips.[1] As far as observation goes, the wandering of the caterpillars among the blossoms seems to prevent the natural formation of pods, and the result is likely to be a very short crop of beans. Reports from different sections of the islands indicate this, and as the stockmen depend largely upon the keawe bean for winter fodder, the serious nature of these two pests is at once appreciated. A more thorough investigation of the matter is contemplated.

The three or four last months of the year were devoted to the collection and systematic study of the Aphidæ present in the islands. The results of this work are given in the following "Synopsis of Hawaiian Aphidæ."

SYNOPSIS OF HAWAIIAN APHIDAE.

In the investigation of the Hawaiian fauna and its systematic elaboration, some of the groups of smaller insects, of great economic importance, received practically no attention whatever, due partly to difficulties in the way of preservation of specimens, and in some cases to lack of scientific interest in insects evidently not indigenous. The Aphidæ, or plant lice,

[1] vide fn. p. 19.

among others, suffered such neglect, although Kirkaldy [1] twice gave lists of known species and described two species as new. The present paper, in which the number of species is increased to 21, four of which are described as new, represents as thorough a study of the family as was possible with limited facilities and time. The writer's collecting was almost entirely confined to Honolulu and its adjacent mountains and extended over less than a year. More extensive collection might have added to the list. The writer acknowledges with thanks the help and encouragement of many co-workers, and is under especial obligation to Mr. Kirkaldy for the loan of literature.

KEY TO GENERA.

1.	Antennæ of seven segments	2
	Antennæ of less than seven segments	8
2.	Antennæ inserted on a frontal tubercle	3
	Antennæ inserted directly on the head	6
3.	Frontal tubercles approximate, head grooved	*Macrosiphum*
	Frontal tubercles not approximate, head smooth or convex	4
4.	Nectaries cylindrical	*Myzus*
	Nectaries more or less clavate, at least not cylindrical	5
5.	Second branch of cubital vein distorted so as to form a closed cubital cell	*Pentalonia*
	Second branch of cubital vein not distorted, wing venation normal	*Rhopalosiphum*
6.	Cubital vein only once forked	*Toxoptera*
	Cubital vein twice forked	7
7.	Nectaries longer than broad, cylindrical	*Aphis*
	Nectaries shorter than broad	*Myzocallis*
8.	Antennæ with six segments	*Eriosoma* (*Schizoneura*)
	Antennæ with five segments	*Cerataphis*

Macrosiphum *Passerini.*

Antennæ nearly always longer than body, on distinct and approximate frontal tubercles; seventh joint mostly longer than

[1] vide Proc. Haw. Ent. Soc., vol. 1, pt. 3, p. 100 (1907), pt. 5, p. 206 (1908).

the third. Wings large, legs long and slender, nectaries long, cylindrical, tail long, ensiform.

There are five species of this genus found in Hawaii, to be distinguished as follows:

1. General color black, with capitate hairs.....*M. kirkaldyi*
   General color green, without capitate hairs..... 2
   General color brownish or yellowish..... 3
2. Greenish without darker markings on abdomen....*M. trifolii*
   Greenish with dark lateral and dorsal markings....*M. rosae*
3. General color dark reddish or brownish and hairy .....*M. sanborni*
   General color yellow with horseshoe-shaped marking on dorsum of abdomen of apterous female.....*M. circumflexa*

Macrosiphum kirkaldyi n. sp.

Apterous female. Dull black, the dorsum bearing transverse rows of white capitate hairs. Sometimes a tinge of dark red on head. Eyes dark red. 1st and 2nd segments of antennæ black, 3rd, 4th and 5th pale with black tips, 6th and 7th dusky black. Legs long and pale, the tips of tibiæ slightly brownish, tarsi black. Nectaries moderately long, pale, black at base. Tail black. Length 1.4 mm.

Winged female. Dull black, thoracic tubercles and head having at times a copperish tinge, in front of and behind prothorax bluish. Eyes dark red, ocelli clear and bordered with black. Antennæ dusky, segments 1 and 2, 6 and 7, and tips of 3, 4 and 5 black. Legs pale, tips of femora, tibiæ, and tarsi black. Nectaries moderately long, cylindrical, wider at base than at apex, mouth conspicuously rimmed, pale, black at base. Tail about half as long as nectaries, ensiform, edges serrate, with two backward-pointing bristles on each side, black, subanal plate fringed with white. Rostrum reaching 3rd coxæ, pale with black tip and base. Wings clear, highly iridescent, veins black and heavily shaded, stigma short, broad, shaded with black, venation abnormal, only one branch to cubital, stigmatic vein much curved, uniting with cubital and branch for part of its length. Antennæ extending beyond the body about one-third of its length, glabrous, 7th segment longer than 3rd, 4th and 5th subequal, 1st, 2nd and 6th smaller than 4th or 5th and

subequal. Third segment with 9-11 circular sensoria, 4th with 4, 5th with 1-4, 6th with one large sensorium. Antennæ on distinct tubercles and close together, tubercles gibbous on inner

FIG. 1.—*Macrosiphum kirkaldyi* wingless viviparous female, enlarged, (original)

apical angle. Body covered with white capitate hairs. Length of body 1.25 mm. Length of antennæ 1.65 mm. Expanse of wings 4.5 mm.

Hab. Oahu, Tantalus (2000), Niu (2000), Palolo (1500) (O. H. S., D. T. F.); on *Acrostichum reticulatum.*

Macrosiphum trifolii Perg.

M. trifolii Pergande, Bul. 44, U. S. Bur. Ent., p. 21 (1904).

Apterous female. Light pea green and polished or somewhat pruinose, yellowish green towards head. Eyes red. An-

tennæ black except segments 1 and 2, which are yellowish green (in immature specimens segments 3, 4 and 5 are paler, only the tips black). Legs long, femora greenish at base, apically brownish, tibiæ brownish to black tip, tarsi black. Nectaries brownish in middle changing to black at apex and to green at base. Tail pale. Length 2.5 mm.—3.25 mm.

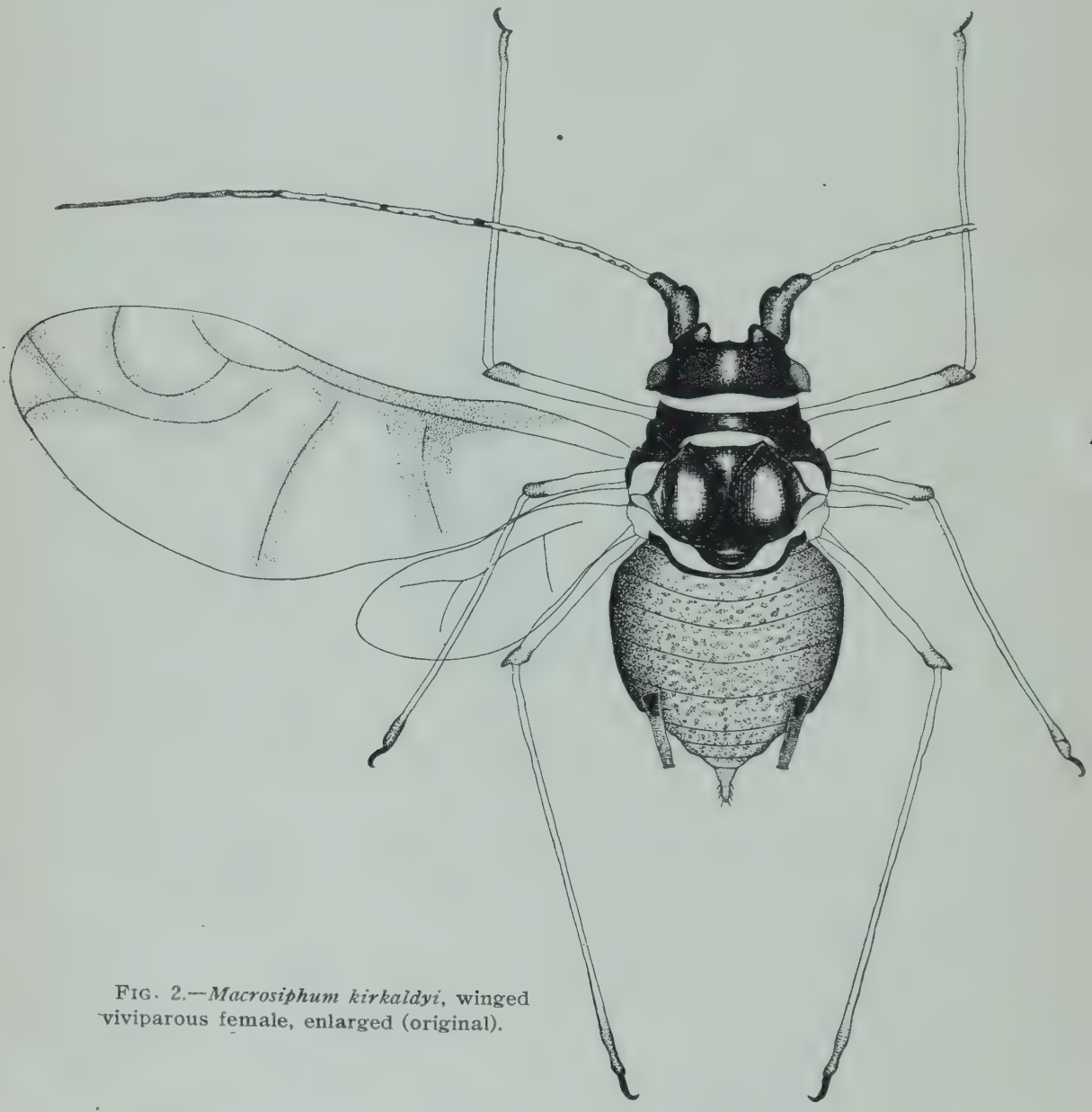


FIG. 2.—*Macrosiphum kirkaldyi*, winged viviparous female, enlarged (original).

Winged female. Light green, head and thoracic tubercles yellowish green. Eyes reddish brown, ocelli close to eye, clear and bordered with black. Antennæ black distally from near base of 3rd segment, 1st and 2nd segments and base of 3rd greenish yellow. Apical half of femora, tips of tibiæ and tarsi black, the remaining portions pale. Nectaries long and slender,

cylindrical, larger at base than at apex, dusky to black and greenish at base. Tail about half as long as nectaries, ensiform, densely covered with minute sharp spines and with four backward-curved hairs on each side, pale. Wings clear, veins thin and brownish, stigma long, narrow and greenish, venation normal. Antennæ extending to or slightly beyond tip of nectaries, hairs sparse and simple, seventh segment longer than third, fourth less than third, fifth less than fourth, sixth, first and second small. Sixteen small circular sensoria on third segment, one large circular sensorium at tip of fifth. Length of body 2.25—3.25 mm. Length of antennæ 3.37 mm. Expanse of wings 8.5 mm.

Hab. Oahu, Honolulu, Tantalus (2000) (D. T. F.); on *Sonchus oleraceus.*

Macrosiphum rosae (Linn.)

Aphis rosae Linn. Syst. Nat. 1, 2, 734 (1735)

Siphonophora rosae Koch. Pflanzenl. 178 (1854-1857)

Apterous female. Shining green. Eyes red. Antennæ long, as long as body, dusky. Legs long, yellowish green, tips of femora, tibiæ and tarsi black. Body long, ovate. Nectaries very long, reaching to or beyond tip of tail, curved, black. Tail long, ensiform, yellow. Length 2.25 mm.

Winged female. Green, head and thorax olive brown, prothorax greenish with darker transverse band. Abdomen lighter green with a row of five dark spots on each lateral margin, and obscure markings on the dorsum between segments two and five. Eyes red. Antennæ black except 2nd segment and base of third. Legs of moderate length, lemon yellow, the apices of femora, tibiæ and tarsi black. Nectaries long, thin, black, reaching to tip of tail, wider at base than at apex. Tail long, light yellow, ensiform, and bent slightly upward. Wings ample, clear, insertions and cubitus yellow. Stigma greenish, veins black, venation normal. Antennæ as long as or slightly longer than body, segments 3 and 7 subequal, 4th much shorter than the preceding but longer than 5th. Third segment with 14 circular sensoria, 8 on 4th segment, 1 on 5th, 1 on 6th. Length of body 1.85 mm. Length of antennæ 1.9 mm.

Hab. Oahu, Honolulu (D. T. F.); Hawaii, Mana (3500), Puuopelu (2000) (G. W. K.); on cultivated roses.

Macrosiphum sanborni Gillette.

M. sanborni Gillette. Can. Ent. 40, p. 65 (1908)

M. chrysanthemi (Oest.) Sanborn Kans. Univ. Sci. Bul., vol. 3, no. 1, p. 73 (1904)

Apterous female. Dark red, almost black, and polished, thorax lighter red, distinctly carinated, the body bearing transverse rows of hairs. Eyes dark red. Antennæ as long as or longer than the body, 3rd segment (except at tip) and base of 4th pale to yellow, the rest black. Legs stout, tip of femur, base and tip of tibia and tarsus black, rest pale to yellow. Nectaries vasiform, moderately long with wide base and narrow mouth, black. Tail about same length as nectaries but extending beyond them, concolorous, the chitinized portions black, ensiform, constricted at middle, with four backward curved hairs. Larvæ cherry red. Length 1.75 mm.

Winged female. Dark cherry brown, the head nearly black, thorax lighter red, tip of abdomen yellowish, body quite hairy, the hairs arranged in transverse rows. Eyes dark red. Antennæ black except base of 3rd segment which is yellow. Legs as in apterous form. Nectaries moderate, cylindrical but wider at base than at apex, with conspicuously rimmed mouth, black. Tail ensiform, upturned, black, about as long as nectaries but extending beyond them, and hairy. Rostrum reaching 2nd coxæ and black. Wings long and slender, extending beyond body by half their length, clear, iridescent, veins thin, dusky, stigma long and thin, yellow, venation normal. Antennæ as long as or longer than the body, more or less glabrous, 3rd segment longest, slightly longer than 7, about twice as long as 5, which is slightly less than 4. Third segment (and 4th) tuberculate with many sensoria, 5 and 6 each with one. Length of body 1.8 mm. Length of antennæ 2 mm.

Hab. Oahu, Honolulu (D. T. F.); on cultivated chrysanthemums.

Macrosiphum circumflexum (Buckt.)

Siphonophora circumflexa Buckton. Mon. Brit. Aphidæ, vol. 1, p. 130.

Apterous female. Yellow with black markings as follows: on prothorax toward lateral margins large spot outward and forward, a smaller one inward and backward, meso and meta-

thorax each large transverse marking, abdominal segments 1, 2, 3, 4 and 5, a large horseshoe shaped marking, curve directed backward, two small transverse markings on segments 6 and 7. Eyes dark red. Antennæ longer than the body, pale except at joints which are black, 7th segment dusky. Antennæ on well-defined tubercles. Legs pale or reddish to tips of tibiæ which are black. Nectaries pale to black rings which are more or less conspicuous. Tail conical, pale. Under side of body greenish yellow except head which is pale.

The winged form has not been observed.

Hab. Oahu, Tantalus (1500) (D. T. F.); on *Physalis peruviana* in the cup of the inflated calyx.

Myzus *Passerini.*

Antennæ nearly as long as the body, on frontal tubercles which are gibbous on inner side. First antennal segment also gibbous. Wings moderately long, venation normal. Nectaries moderately long, cylindrical. Tail moderately long.

There are two species of this genus in Hawaii, to be distinguished as follows:

1. Body of both apterous and winged forms wholly black, antennæ not as long as the body.....*M. citricidus*
   Body of apterous female yellowish green, of winged female generally green, only head, part of thorax and abdominal markings black, antennæ longer than the body.....*M. persicae*

Myzus citricidus Kirkaldy.

M. citricidus Kirkaldy. Proc. Haw. Ent. Soc., vol. 1, pt. 3, p. 100 (1907).

Apterous female. Form and color of *Myzus cerasi* (larva lighter). Eyes dark red. Antennæ black proximally and distally, segments 3, 4, and base of 5 whitish. Legs: most of femora, distal end of tibiæ and tarsi black, remaining portions whitish. Nectaries large, curved, wider at base than at apex, with inconspicuous rim, black. Tail large, conical, hairy, black. Small fleshy tubercle on thorax and succeeding segments. Antennæ nearly two-thirds as long as the body, on widely separated frontal tubercles. Length of body 2.15 mm.

Winged female. Form and general appearance of *Myzus*

cerasi. Black, shining, closely reticulate on tergites, abdomen above and below often widely dark brown medio-longitudinally. Eyes nearly black. Antennæ black, fourth and fifth segments white at base. Legs: femora black except at base, tibiæ whitish to tips, which with tarsi are black. Nectaries long, reaching tip of tail, slightly wider at base than at apex, not conspicuously rimmed, black at least basally. Tail conspicuous, about half the length of nectaries, ensiform, hairy, bent upward, black. Wings large, clear, cubitus and stigma whitish sordidly, veins pale fuscous, venation normal. Antennæ nearly as long as body, 7th segment longer than 3rd, 3rd and 4th subequal, each longer than 5th, 3rd segment with about 12 circular sensoria. A small tubercle on lateral margins of prothorax and others on lateral margins of abdomen. Antennæ on widely separated frontal tubercles. Length of body 1.75 mm. Length of antennæ 1.6 mm. Expanse of wings 5.25 mm.

Hab. Oahu, Honolulu (D. T. F.); Hawaii, Mana (G. W. K.); on *Citrus aurantium*.

Myzus persicae (Sulz.)

Aphis persicae Sulz., Kennzeichen Insecten, p. 105 (1761).

Aphis dianthi Schr., Fauna Boica II (1801).

Apterous female. General color yellowish green without black markings. Body long and tapering posteriorly. Eyes dark red. Antennæ and legs pale except at tips, which are dusky to black. Nectaries pale. Tail concolorous. Antennæ reaching base of nectaries, which are quite long. Tail long, ensiform. Length of body 1.8 mm.

Winged female. Head and thorax black or blackish. Abdomen green with dark (almost black) markings on dorsum of segments 4, 5 and 6, and sometimes extending to segments 3 and 7. Spots of similar color on lateral margins of segments 2, 3 and 4. Eyes dark red. Antennæ black. Legs pale, distal portions of femora, tibiæ and tarsi black. Nectaries long, thin, cylindrical (slight constriction at about middle), mouth conspicuously rimmed, black or blackish. Tail black, moderate, ensiform. Wings clear, iridescent, insertions yellow, stigma slightly dusky, veins thin, black, venation normal. Antennæ somewhat longer than the body, 7th segment slightly longer than the 3rd, 4th less but somewhat longer than 5th, 3rd seg-

ment with 10-12 circular sensoria in a single row. Length of body 1.75 mm. Length of antennæ 2 mm.

Hab. Oahu, Honolulu (D. T. F.); on *Brassica oleracea.*

Pentalonia *Coquerel.*

Similar to *Aphis* but with remarkable venation. Third discoidal vein and its first branch (cubital) straight and anastomizing with a deformed stigmal vein, so that there appears, 1st, an inferior nerve (3rd discoidal) extending to basal margin, 2nd, a superior nerve (cubital) which bifurcates, the inferior branch extending to the basal margin, the superior branch again bifurcating, its proximal member being simple, its distal member again bifurcating before the margin is reached: there are thus formed five apical cells with approximately straight boundaries.

Pentalonia nigronervosa Coq.

P. nigronervosa Coquerel. Ann. Soc. Ent. France, p. 279 (1859).

Apterous female. Mahogany brown and somewhat polished, the larvæ and pupæ usually paler. Eyes reddish. First and second antennal segments almost black, third pale brown, fourth and fifth pale to black tips, sixth and seventh almost black. Segment three without sensoria but four and five with the usual large sensoria near the tips. Legs normal, outer third of femora, tip of tibiæ and tarsi black. Median light area on head and thorax. Dorsum of abdomen in median elevated portion almost black. Length 1.4 mm.

Winged female. Darker than apterous, almost black, thoracic tubercles prominent and polished. Antennæ dusky, first and second segments black, third pale in basal portion. Legs as in apterous form. Nectaries of moderate length, incrassate, mouth flaring, with distinct rim, black. Tail short and inconspicuous, white. On each segment a transverse row of minute white hairs. Wings clear, veins strong and black, somewhat shaded, stigma grayish black. Venation abnormal, cubital vein two forked and distorted, the stigmatic vein uniting with the outer branch of the cubital so as to form a distinct closed cubital cell contiguous to the stigmal cell. Hind wings with

only one branching vein. Antennæ as long as the body, the first segment much the stoutest, frontal tubercles prominent and gibbous on inner apical angle, seventh segment much longer than 3rd, 3rd about as long as 4th and 5th together, 6th, 4th and 5th, and 1st and 2nd subequal in length. Third segment with about 8-9 sensoria, 4th with 6 sensoria, three of them near the middle of the segment, 3 near the distal end, 5th with 3 smaller circular sensoria, 5th and 6th with the usual large sensorium near apex. Length of body 1.8 mm. Expanse of wings 4.25 mm.

Hab. Oahu, Honolulu (D. T. F.); on cultivated banana (*Musa* spp.)

Rhopalosiphum *Koch.*

Antennæ on frontal tubercles which are not distinctly approximate, about as long as or longer than the body. Nectaries larger in the middle than at either end or distinctly clavate, moderately long. Tail more or less small and inconspicuous, sometimes conical.

Rhopalosiphum violae Perg.

R. violae Pergande. Can. Ent. vol. 32, p. 29 (1900).

"Apterous females dark cherry-brown and polished, the larvæ and pupæ generally somewhat paler. Eyes dark brown, third joint of antennæ more or less distinctly of a paler color than the body, the remaining joints black. Legs purplish, the femora darkest towards the end and the apex of the tibiæ and the tarsi black. Nectaries purplish. Head and thorax of the pupæ generally paler than the rest of the body.

"Winged females also dark cherry-brown or purplish-brown, the antennæ, thoracic lobes, terminal two-thirds or more of femora, apex of tibiæ and tarsi black; rest of the legs of a dull yellowish colour, with a tinge of purple. Nectaries and tail dusky. Wings clear, the veins strong and black and conspicuously shaded; stigma black; stigmal vein short and strongly curved. Antennæ of all, very long and slender, reaching considerably beyond the end of the body; joint 6 with its spur is much longer than the 3rd, joints 4 and 5 are subequal in length, and each of them somewhat longer than the 3rd; there are numerous sensorial tubercles on joint 3 and a few on joint 4,

while all of them are sharply serrate. The first joint is very much the stoutest, and bulging out strongly about the middle at the inner side; frontal tubercles prominent and gibbous at the inner apical angle. Legs long and slender. Nectaries clavate, reaching to the tip of the abdomen. Tail short and inconspicuous. Length of winged and apterous females about 1.6 mm. Expanse of wings about 5 mm."

I have copied Pergande's description of the species (supra) as my material was in such poor condition as to make it impossible to write an adequate description from it.

Hab. Oahu, Tantalus (1500-2000) (D. T. F.); on cultivated violets. I presume it was the same species that Mr. Kirkaldy observed at Puuopelu on Hawaii.

Toxoptera *Koch.*

Antennæ on no frontal tubercles, or on very inconspicuous ones, not approximate, sometimes as long as, usually a little shorter than the body. Legs moderate. Nectaries moderate, not as long as the breadth of the segment in which they arise. Tail conical. Cubital vein only once forked.

There are two species of this genus found in Hawaii, to be distinguished as follows:

1. General color of winged and wingless female black ..... *T. aurantiae*
   General color of winged female green, wingless female brownish yellow ..... *T. caricis*

Toxoptera aurantiae Koch.

T. aurantiae Koch. Pflanzenl., p. 254 (1854-7).

Apterous female. Dull black with sometimes a brownish tinge on head (the larvæ somewhat pruinose). Eyes nearly black. Antennæ nearly as long as body, black, 1st and 2nd segments black, 3rd, 4th, and 5th white with black at apex, 6th mostly black, 7th white with black tip. Legs fairly stout, front femora mostly brownish, black at tips, middle and hind femora mostly black, brownish at base, tibiæ pale dusky with black tips, tarsi black. Nectaries short, cylindrical, wider at base than at apex, mouth inconspicuously rimmed, entirely black. Tail small, black, conical and bent upward, beset with hairs. Length of body 1.52 mm.

Winged female. Somewhat smaller than apterous, black, abdomen on sides and backward from nectaries brown, a pair of tubercles on each side of thorax pale. Antennæ a little longer than the body, 1st and 2nd segments black, 3rd, 4th and 5th white with black apex, 6th mostly black, 7th white with black tip. Legs fairly stout, front femora brownish at base, black at apex, middle and hind femora black, tibiæ brown with black tip, tarsi black. Nectaries short, cylindrical, wider at base than at apex, entirely black. Tail conical, rather thick, black, beset with hairs. Wings clear, insertions yellowish, veins brownish, stigma long, narrow, black, venation normal, stigmatic vein extending from apex of stigma and much curved. Antennæ not approximate and hardly on frontal tubercles, 7th segment longer than 3rd, 4th and 5th subequal, 3rd with 8 large circular sensoria, smaller sensoria on 4th and 5th, on each of

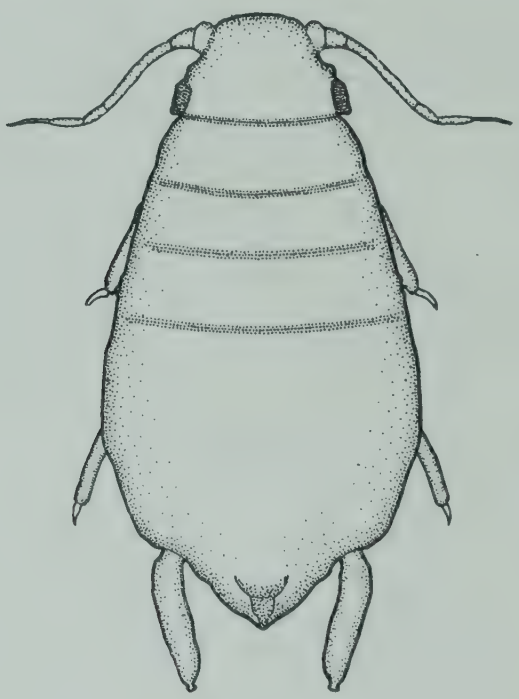


FIG. 3.—*Toxoptera caricis*, wingless viviparous female, enlarged, (original).

which there is the usual single large sensorium. Length of body 1.16 mm. Expanse of wings 4.3 mm.

Hab. Oahu, Tantalus (2000), Niu (2000), Palolo (1500) (O. H. S., D. T. F.); on *Pelea, Straussia, Coffea.*

Toxoptera caricis n. sp.

Apterous female. Brownish yellow, lighter at the margins. Eyes dark red. Antennæ, legs and nectaries concolorous. Tail

darker. Rostrum with black tip. The body is broadly oval and flat, so that the legs seem close together. Integument hard. Antennæ short, less than half the length of the body, third segment the longest, 7th which is filiform and about one-third of 3rd nearly equal to 4th, 5th still smaller, less than one-half of 4th. Nectaries very large, extending half their length beyond tail; base and apex much constricted, the mouth rimmed; otherwise broad for their length. Tail small, ensiform. Length of body 1.44 mm.

Pupa similar to apterous female with the exception of pale wing cases.

Winged female. Green, head and thorax dark olive brown, prothorax greenish yellow with dark olive-brown band. Abdomen light green. There are usually a few small dark-red spots toward the base in center on dorsum. Eyes dark red. Antennæ dark brownish black. Legs pale to tips of tibiæ, which with tarsi are black. Nectaries moderate, reaching beyond tip of body, pale to green, clavate and much bent. Tail short, conical and black. Wings ample, clear, iridescent, insertions light yellow, stigma long, thin, dusky, veins black. Cubital vein only once forked. Antennæ about two-thirds length of body, reaching base of nectaries, 3rd segment the longest, 7th less than 3rd but longer than either 4th, 5th or 6th, which are subequal, 3rd, 4th and 5th segments cicatrized with many circular sensoria, one large circular sensorium at tip of 6th. Length of body 1.5 mm. Length of antennæ .9 mm. Expanse of wings 4.65 mm.

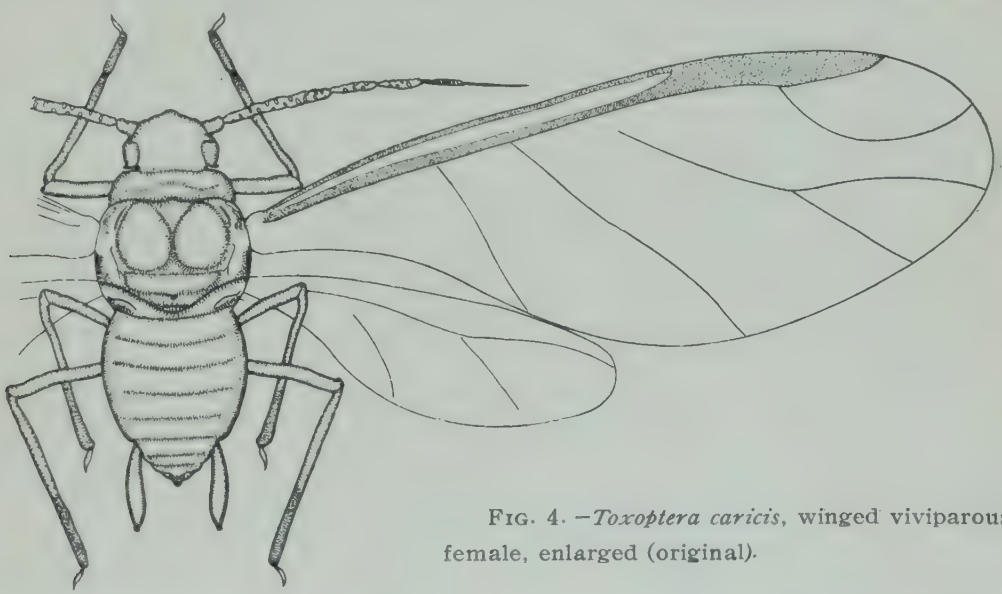


FIG. 4.—*Toxoptera caricis*, winged viviparous female, enlarged (original).

Hab. Oahu, Pauoa V. (1500-2000) (D. T. F.); on a species of *Carex*.

APHIS *Linnaeus.*

Antennæ on no frontal tubercle, or on very inconspicuous ones, usually shorter than the body. Wings rather short and broad, deflexed in repose, venation typical. Legs moderately long. Abdomen short and broad, rounded or obtuse behind. Nectaries moderately long, cylindrical or slightly incrassate, sometimes small. Style usually short, more or less thick, conical.

There are seven species of this genus found in Hawaii, to be distinguished as follows:

1. Nectaries conspicuously short, about twice as long as wide ..... *A. sacchari*
   Nectaries not so short, much more than twice as long as wide 2
2. Third antennal segment with not more than 12 large circular sensoria—from 3 to 12 3
   Third antennal segment with more than 12 large circular sensoria—14 to 20 5
3. General color black, apterous female with white waxy secretion on dorsum ..... *A. bambusae*
   General color green or mixed with green, apterous females without waxy secretion 4
4. General color green, sometimes with reddish tinge, dorsum much marked with black, 3rd antennal segment with 10-12 circular sensoria ..... *A. swezeyi*
   General color dark green to almost black, sometimes mixed with orange yellow, dorsum with lateral black spots, 3rd antennal segment with 3-8 circular sensoria ..... *A. gossypii*
5. Third antennal segment conspicuously cicatrized, wider than following segments, apterous female and larvæ covered with a mealy or woolly substance ..... *A. brassicae*
   Third antennal segment not conspicuously wider than the following segments nor cicatrized, apterous female and larvæ not covered with a woolly substance 6
6. General color of apterous females dark green ..... *A. maidis*
   General color of apterous females yellowish green ..... *A. myosotidis*

Aphis sacchari Zehntner.

A. sacchari Zehntner. Arch. Java Suiker. V, p. 551 (1897) and IX, p. 673 (1901).

Apterous female. Greenish (larvæ paler). Eyes dark red. Antennæ slightly more than half the length of the body, black distally, 1st to 5th segments pale, 6th and 7th black. Legs pale to tarsi, which are black. Nectaries conspicuously short, black. Tail moderately long, much wider at base than at apex, which is conical, black. Length of body 1.3 mm.

Winged female. Head, thorax and transverse band on neck black, prothorax and abdomen light to dusky green. Eyes dark red. Antennæ black, except base of third segment, which is green. Legs light to tarsi, which are black. Mid and hind femora sometimes dusky distally. Nectaries conspicuously small, black, wider at base than at apex, which has a distinct rim. Tail small, conical, black and hairy. Wings clear, insertions yellowish. Stigma dusky, veins black, venation normal. Antennæ two-thirds as long as body, 7th segment considerably longer than 3rd, 5th less but a little longer than the 4th. Third segment with about 7 circular sensoria. Length of body 1.6 mm. Length of antennæ 1.08 mm.

Hab. Oahu, Honolulu, and probably throughout islands where sugar cane is grown (O. H. S., G. W. K.); on sugar cane (*Saccharum officinarum*).

Aphis bambusae n. sp.

Apterous female. Black beneath flocculent white waxy secretion. Eyes reddish black. Antennæ generally a dull white, segments 1, 2, 6, and 7 towards tip black. Legs pale to tarsus which is black. Coxa and trochanter black, distal end of femur and proximal end of tibia slightly blackish. Nectaries short, not reaching the end of the body by twice their length, black. Tail short, conical, dusky with four pairs of hairs directed backward. Two lateral rows of black spots dorsally on abdomen converging at point opposite base of nectaries. Two lateral rows of black spots on venter which do not converge. Antennæ about as long as the body on slight erect tubercles. The waxy secretion is apparently absent across the thoracic region and around the base of the nectaries. Length 1.07 mm.

Winged female. Much smaller than the apterous form.

Waxy secretion absent. Color black. Eyes black. Antennæ dusky to black, the two basal segments black. Legs black to tip of the femur, tibia pale except extreme base and tip which are black, tarsus blackish. Nectaries small, slightly longer than tail, black. Tail small, dusky, with a pair of hairs which are directed backward. Wings extending greatly beyond body, clear, iridescent, stigma dusky, veins black, venation normal, antennæ about one-fourth longer than the body. Seventh segment the longest, about twice as long as 3, 3, 4 and 5 sub-

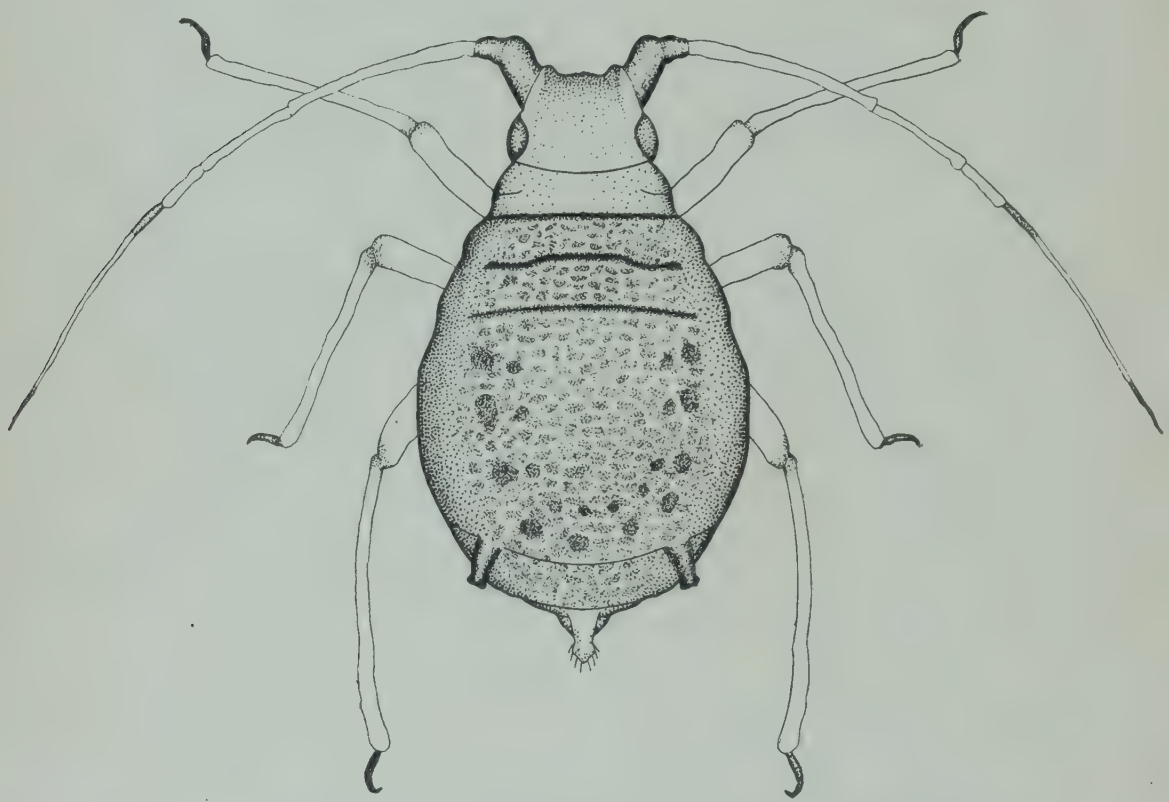


FIG. 5.—*Aphis bambusae*, wingless viviparous female, enlarged, (original).

equal. Third segment with 8 circular sensoria in a straight line and tubercular, 4th segment with 6 and also tubercular, 5th segment with 7 but only slightly tubercular, 1st segment broad. Length of body .8-1 mm. Length of antennæ 1.17-1.25 mm. Expanse of wings 3.4 mm.

Hab. Oahu, Honolulu (D. B. K., D. T. F.); on a bamboo (*Phyllostachys?*).

Aphis swezeyi n. sp.

Apterous females. General color green, mottled with black, sometimes lightly covered with mealy bloom. Larvæ lighter

green without black markings. Eyes dark red. Antennæ about half the length of the body, dusky to black, bases of segments 3 and 4 dirty white. Legs long, black, base of femora and tibiæ except tip white. Head black, thoracic segments with broad, black transverse bands and lateral spots. Abdominal segments to one in front of nectaries with large black lateral spots and dorsal central markings which decrease in size caudad. Segment in front of nectaries has wide, thin, transverse, black marking (broadly interrupted), segment with nectaries has some indistinct central dorsal markings, the two following seg-

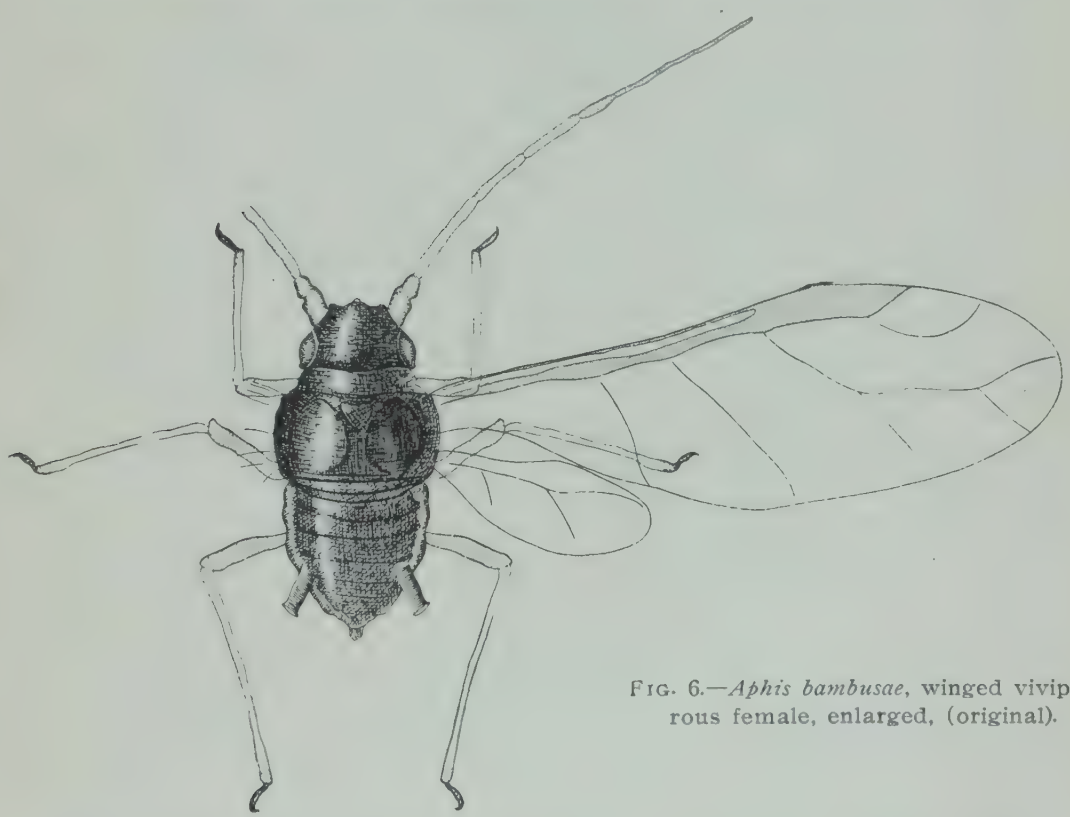


FIG. 6.—*Aphis bambusae*, winged viviparous female, enlarged, (original).

ments each a transverse black band. There are six large lateral spots in front of nectaries and a smaller spot just behind them. On the ventral surface, which is green, obscured by whitish bloom, there is a lateral row of smaller markings from the 1st segment caudad. Thoracic and abdominal tubercles well marked. Nectaries short, not reaching tip of tail, cylindrical, more or less imbricated, with distinct rim, black. Tail short, conical, tip black. Length 1.62 mm.

Winged female. Head black, thorax shining black, prothorax with transverse black band, on either side of which it is green or reddish, abdomen dull green with a reddish tinge.

There are three large lateral black spots on each side, with corresponding thin transverse markings extending medad in front of nectaries; behind nectaries is one lateral black spot on each side and the following two segments have each a transverse black band. Eyes dark red. Antennæ black except base of third segment. Legs dusky to black except base of femora and tibiæ, only the point of which is black. Nectaries

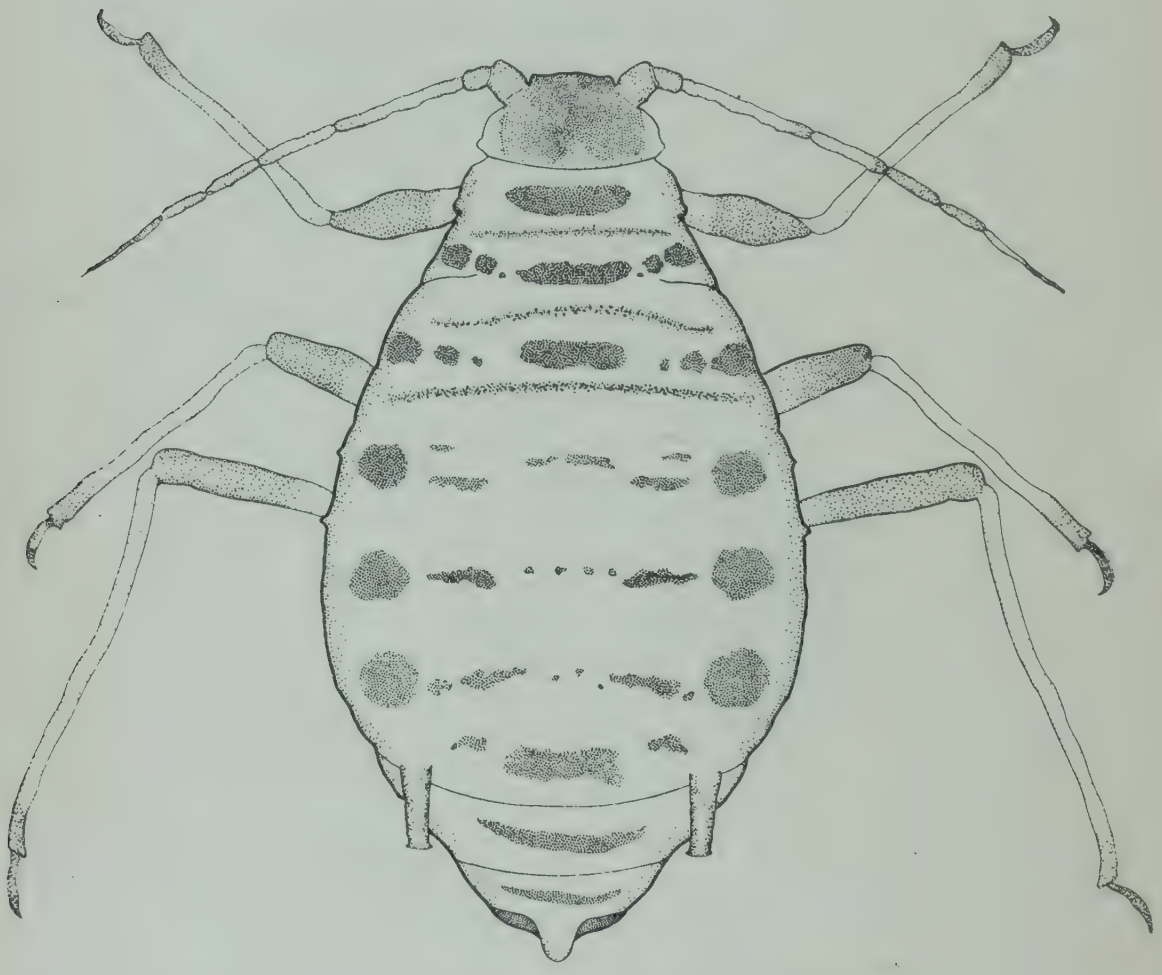


FIG. 7.—*Aphis swezeyi*, wingless viviparous female, enlarged, (original).

very short, not reaching tip of tail by much more than their length, black, conspicuously rimmed. Tail moderately long, black. Wings clear, insertions reddish, cubitus, stigma and veins dusky. Venation usually normal, sometimes second fork of cubitus absent, stigmatic vein much curved. Antennæ a little more than one-half the length of the body, third segment longest, nearly a third longer than 7th, 4th considerably less than 7th but longer than 5th, 6th smallest; third segment with

10-12 circular sensoria, one on the 4th, the 5th and the 6th. Length of body 1.61 mm. Length of antennæ .9 mm.

Hab. Oahu, Halawa (O. H. S., D. T. F.); on *Gnaphalium*.

Aphis gossypii Glover.

A. gossypii Glover. Pat. Office Report 1854, p. 62.

A. gossypii Glover. Pergande, Ins. Life 7, p. 309-315 (1895).

Apterous female. Very variable in color, light lemon yellow to dark greenish with obscure markings and even dull and polished black,[1] sometimes pulverulent with a bluish tinge. Eyes red to deep black. Antennal segments 1, 2, 6, 7 and tip of 5 dusky to black, remainder pale. Legs pale to tips of tibiæ, which with tarsi are black, femora sometimes blackish distally. Nectaries short, black. Tail short, conical, concolorous with dusky tip and bearing two backward curving hairs. Antennæ about half as long as body or slightly longer. Prominent conical and fleshy tubercles on either side of prothorax and behind nectaries and four smaller tubercles on each side of abdomen in front of nectaries. Length of body 1.2-1.8 mm.

Winged female. Head, thorax and transverse band on neck black, thoracic tubercles conspicuous and shining, neck and prothorax green, sometimes very dark, abdomen orange yellow in front, green behind, or blackish with green markings. When light, four lateral black spots can be distinguished, the last at base of nectaries. Eyes dark red to nearly black. Antennal segments 1 and 2 black, 3 mostly black, white at base, 4, 5 and 6 white basally, black apically, 7 black. Legs pale to tips of

---

1 Note. It is difficult to decide whether there is one or two species on this long list of food plants. The wide differences in size and color led me to believe at first that there were two distinct species, but a more careful examination of a great mass of material shows no distinguishing character that is constant for any part of it. I am inclined to believe, however, that the aphid found on *Medicago denticulata*, *Phaseolus lunatus* and *Portulaca oleracea* is different from *A. gossypii*, which as seen on cotton is never a polished black. Mature apterous individuals of the aphid on the above-mentioned plants have large, swollen abdomens, which are polished black in color with surface reticulation. The alate forms are also sometimes somewhat polished black, obscuring a dark green beneath. It is interesting to note in this connection that Dr. Filippo Silvestri in his report on a recent visit to the Hawaiian Islands (Bol. Quind. Soc. Agr. Ital., 14 (1909), no. 8, p. 344) states that he observed *Aphis papaveris* on beans. The species may be *A. papaveris* or *A. medicaginis*, but it does not answer closely the description of either of these species, and it will be necessary to make more extended observations to settle the matter.

tibiæ, which with tarsi are black, hind and sometimes mid femora black. Nectaries black, moderately long, cylindrical, wider at base than at apex, mouth not conspicuously rimmed. Tail concolorous, pale or dusky, moderately long, conical. Wings clear, iridescent, insertions and cubitus pale yellow,

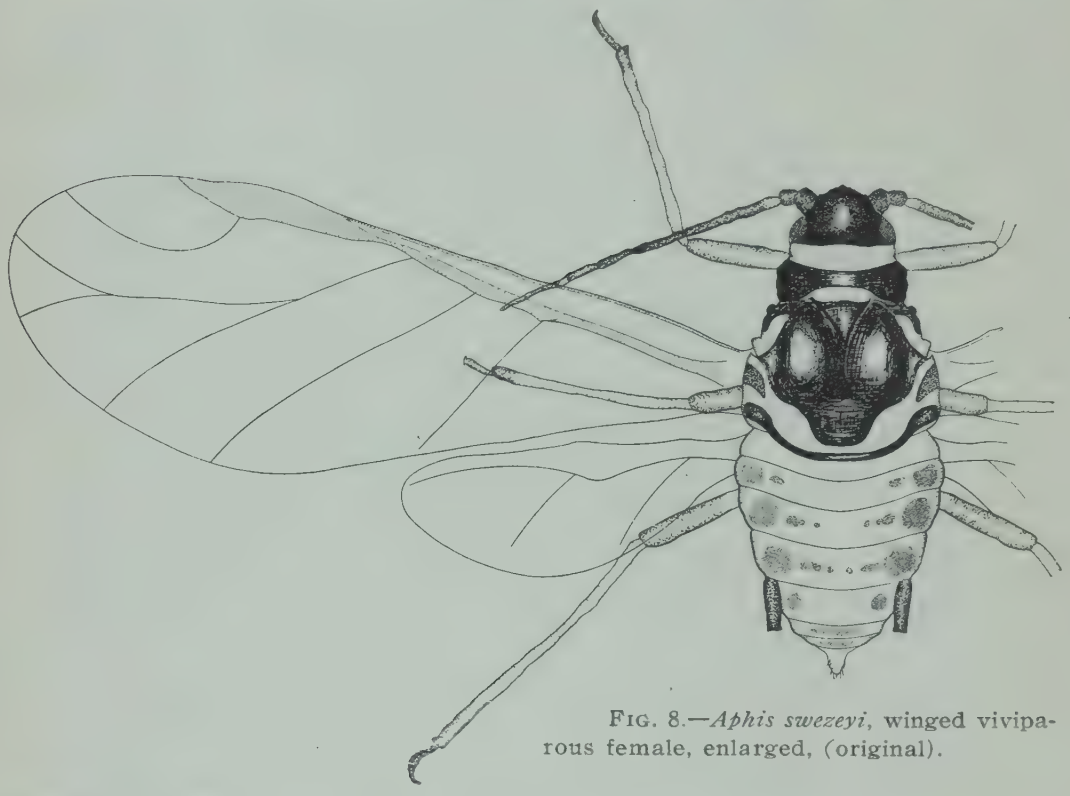


FIG. 8.—*Aphis swezeyi*, winged viviparous female, enlarged, (original).

stigma yellow to dusky, veins brown, stigmatic vein much curved, venation normal. Antennæ one-half to two-thirds as long as body, in latter case nearly or quite reaching base of nectaries, 7th segment a little longer than 3, 4th and 5th subequal and each less than 3. Third segment with 4-8 large circular sensoria. Length of body 1.2 mm.-1.8 mm. Length of antennæ about 1 mm.

Hab. Oahu, Honolulu, Wahiawa, Waipahu mauka, Kunia, Tantalus (D. T. F.); on *Gossypium, Cucumis, Arum esculentum, Hibiscus rosasinensis, Medicago denticulata, Phaseolus lunatus, Portulaca oleracea, Cuphea, Bidens.*

Aphis brassicae Linn.

A. brassicae Linn. Syst. Nat. 1, 2, p. 734 (1735).
A. brassicae Linn. Fab., Ent. Syst. IV, p. 218.
A. brassicae Linn. Koch, Pflanzenl., 149-150 (1854-57).

Apterous female. Long oval, plentifully covered with a whitish mealy coat. When this is removed, the body beneath

is greenish with a row of 8 black spots a little removed from lateral margin. Eyes black. Antennæ green with black tips, shorter than body. Legs black. Nectaries very short, black. Tail small, black. Length of body 2 mm.

Winged female. Head, thoracic tubercles and transverse bar on neck black, prothorax and abdomen yellowish green with a row of fine punctures on each lateral margin and several obscure transverse dorsal markings. Eyes black. Antennæ dark brown to black. Legs dusky brown, pilose. Nectaries dark brown, black at tips, short. Tail small, conical, hairy, dark green or brown. Wings clear, with stout coarse veins and dark stigma. Antennæ about three-fourths as long as body, 3rd segment longer than 7th, 4th less than 7th but longer than 5th, third segment much cicatrized with more than 20 circular sensoria. From the fourth segment to the tip the antennæ are much more slender than in 3rd and basal segments. Length of body 2 mm. Length of antennæ 1.5 mm.

Hab. Oahu, Honolulu, Wahiawa (D. T. F.); on *Brassica oleracea*.

Aphis maidis Fitch.

A. maidis Fitch. N. Y. Rep't 1, 318 (1855).

Apterous female. General color dull dark green, the head, bases of nectaries and lateral and caudal margins generally dull black, body emarginate. Eyes dark red. Antennæ dusky to black proximally and distally, 3rd, 4th and 5th segments more or less pale, antennæ about half as long as the body. Legs black, femora sometimes pale. Nectaries black, not reaching tip of tail by more than their length. Tail black. Length of body 1.4 mm.

Winged female. Head, thorax and wide band across neck black, thoracic tubercles prominent. Neck on either side of band dark green. Abdomen light green, five lateral black spots, four before and one back of nectaries. Eyes dark red. Antennæ black. Legs black, front femora sometimes pale. Nectaries small, not reaching tip of tail by their length, sometimes incrassate, without conspicuous rim, black. Tail small, hairy, with subanal plate black. A distinct fleshy tubercle on lateral margins of penultimate abdominal segment. Wings clear, insertions and cubitus green, stigma dusky, veins thin and brown, venation normal. Antennæ more than half as long as the body,

3rd segment longer than 7th, 4th slightly longer than 5th but shorter than 7th. Third segment with 14 circular sensoria. Length of body 1.5 mm. Length of antennæ 1 mm.

Hab. Oahu, Honolulu, Kunia (D. T. F.); on sorghum (*Andropogon vulgare* var. *saccharatum*), corn (*Zea mays*).

Aphis myosotidis Koch.

A. myosotidis Koch. Pflanzenl., p. 57 (1854-57).

Apterous female. Yellowish green. Eyes dark red. Antennæ pale to sixth segment, 6th and 7th segments black. Legs pale to dusky, tarsi black. Nectaries concolorous, their tips black. Tail short, thick, hairy, concolorous. Body emarginated. Pupæ greenish.

Winged female. Head and thorax shining black, thoracic tubercles prominent, prothorax and neck green with a transverse darker band. Abdomen green with a darker area caudad of 2nd abdominal segment, which behind the nectaries takes the form of two transverse bands; four black spots on each lateral margin in front of nectaries. Antennæ black. Legs greenish to dusky, tips of femora, tibiæ, and tarsi black. Nectaries short, not reaching tip of tail, cylindrical and distinctly rimmed, black, base greenish. Tail short, thick, tip rounded, beset with hairs, concolorous, black beneath. Wings clear, insertions and cubitus pale greenish, stigma dusky, stigmatic vein much curved, nerves thin, black, venation normal. Antennæ short, not reaching base of nectaries, 7th segment a little longer than 3rd, 4th longer than 5th but only three-fourths the length of the 3rd, third segment with 15-16 large circular sensoria and a few smaller ones, the usual large circular sensorium at tip of fifth segment. Length of body 1.5 mm. Length of antennæ 1.1 mm.

Hab. Oahu, Tantalus (1000), Pauoa V. (1000) (D. T. F.); on *Erechtites* sp.?

Myzocallis *Passerini.*

Antennæ on no frontal tubercles, smooth, seventh segment longer than 6th, front wings with cubital vein twice forked, posterior wings with two oblique veins, nectaries tuberculiform or subobsolete.

Myzocallis kahawaluokalani Kirkaldy.

M. kahawaluokalani Kirkaldy. Proc. Haw. Ent. Soc., vol. 1, pt. 3, p. 101 (1907).

"Winged female. Pale yellowish, marked with pale brownish fuscous, principally as follows: Head dorsally with a mediolongitudinal line and a speck on each side of this, and lateral margins broadly, posterior margin narrowly; irregular, broad, submedian bands down the pronotum, lateral margins narrowly; a suboval, interiorly pale, sublateral spot on mesonotum, a goblet-shaped mark in the middle (the bowl anteriorly, the stem posteriorly), posterior margin broadly; a large irregular transverse spot near the base of abdomen; antennæ whitish, first two segments and apices of 3rd-5th pale brownish fuscous. Eyes bright pale vermeil. Abdomen dorsally and sublaterally with numerous fuscous-ringed tubercles which bear scarcely perceptible hairs, with two contiguous fuscous mammiform tubercles near the base in the middle, etc. Tegmina hyaline, very strongly particoloredly iridescent, subcostal ('costal') cell and stigma, veins and a V apically, pale fuscous. Legs pale, fore and middle femora with a fuscous annulation, hind femora broadly fuscous, apically, hind tibiæ fuscous basally; coxæ more or less fuscous. Honey-tubes short, pale, fuscous. Antennæ scarcely as long as the body, 6, 5, 30, 24, 22, 14, 12, the seventh not really separated from the sixth. Stigma rather long, longer than broad, curved. Length to apex of abdomen about 1.25 mill., to apex of flight organs about 2 mill.

"Hab. Oahu, Honolulu, on *Lagerstroemia indica*, an introduced plant (G. W. K.); also on other shrubs.

"Nymph. Pale yellow, eyes red as in adult. Head, nota and abdomen multituberculate dorsally and laterally, each tubercle with a black capitate bristle."

I have copied the original description of this species, (supra) as I have not seen specimens myself.

Eriosoma *Samouelle* (Schizoneura *Hartig*).

Antennæ six-segmented, cubital vein only once forked. Posterior wings with two oblique veins, which usually originate close to each other, sometimes in contact.. The antennæ are short, those of the winged individuals extending beyond the end of the thorax, those of the apterous individuals usually

reach only to the end of the prothorax, third segment longest. No visible nectaries. Body usually rather broad, elliptical in the winged and broadly ovate in the apterous individuals. Colors are usually black, brown or reddish. Rostrum rather long and slender.

Eriosoma mali Samouelle.

Eriosoma mali Samouelle. Entom. Useful Companion, p. 232 (1819).

Schizoneura lanigera (Hausm.), Fitch, Cat. Homoptera N. Y. 67 (Lint. Rep. NY. Ent. 9, 411).

"Apterous individuals. About one-tenth of an inch long; reddish brown and covered above with a white, cottony secretion; antennæ short, and pale yellow; legs yellowish; knees brown; without honey-tubes, but with a circular cicatrix in place of each.

"Winged individuals. Antennæ shorter than the head and thorax, and varying in color from brown to black; head and thorax black, a brownish ring at the collar; the abdomen chocolate brown; legs brownish; wings hyaline with the veins and stigma deep brown; body enveloped in a white, cottony secretion. Serville and Amyot give the length of the apterous individuals as only eight-hundredths of an inch; they described the winged individuals as less and with the body almost naked."

I have copied the description given in Thomas,[1] as my material was in such poor condition as to make it impossible to write an adequate description from it.

Hab. Hawaii, Waiki (4500) (J. E. H.); on apple (*Pyrus malus*).

Cerataphis *Lichtenstein.*

Antennæ five segmented, the first two segments smooth, the remaining ones ringed. Third segment the longest, fourth and fifth nearly equal. Eyes large. Nectaries obsolete. Eyes of larva nearly obsolete. Head furnished with two minute characteristic frontal horns. Legs and antennæ very short and largely concealed by a disc of waxen filaments arising from peripheral glands.

[1] Thos. Rep't Ent. Ill. 8, p. 126 (1880).

Cerataphis lataniae (Boisd.)

C. lataniae Lichtenstein. Bull. France (6) 2, p. 16 (1882).

"Apterous female. Size of body 1.52x1.27 mm. Antennæ .25 mm. Coccus-like. Color rich brown, to the naked eye nearly black. Form oval or nearly circular. Edge of the body terminated by a string of minute transparent glands from which a clear disc of wax-like substance is secreted. This disc is striated and slightly fimbriated. It entirely surrounds the insect and hides the antennæ and legs below. In the spring of the year two or three pale folds occur across the dorsum of the insect.

"Antennæ very short; four jointed, the first and second joints nearly equal; the third the longest, and about double the length of the second. The fourth joint ends in a considerable nail, which, added to the rest, makes the whole joint nearly as long as the third. The front is furnished with two short projections or horns, the use of which is unknown. Eyes very minute; brown. Legs very short and normally formed like *Aphis;* ending with the usual tarsus and two claws, without the capitate hairs to be seen in coccus.

"Rostrum about one-fourth the length of the body. Cauda tuberculate, with two small papillæ. The under side is paler and mottled with brown.

"The young, born from the above insects, are much less coccus-like and do not greatly resemble their parents. After a short time they moult and become of a pale, ochreous green color. The wax glands soon after show themselves at the circumference of their bodies, and the growth of the disc is rapid and very interesting under the microscope.

"Winged female. Expanse of wings 4.06 mm. Size of body 1.77 mm. x 1.01 mm. Antennæ .88 mm. The imago apparently is very rare, for only three mutilated specimens are at present known. It has not yet been taken in England; but I have been able to make the above measurements from a specimen mounted by M. Richter of Montpelier.

"General color yellow. Antennæ with five articulations: the last three joints are much ringed. Vertex flat and without the horns seen in the larva. Eyes large; stemmata obvious. Wings folded flat on the back. Cubital vein is once forked, and it does not reach to the cubitus. First and second oblique veins unite

just before they touch the cubitus. Rostrum reaches to the second coxæ. Legs short, tarsi with two claws.

"The general appearance of the larva is so coccus-like that the venation shown by the imago is a little unexpected."

I have copied from Buckton [1] as the three or four specimens in my collection could not be used to frame an adequate description.

Hab. Oahu, Honolulu (G. W. K., D. L. VD.); on fan palm (*Pritchardia*).

[1] Buckton. Monograph British Aphidae, vol. IV, p. 198.

REPORT OF THE HORTICULTURIST

By J. E. Higgins.

FRUIT-MARKETING INVESTIGATIONS.

The chief work in horticulture, during the first part of the year was a continuation of fruit-marketing investigations. Attention was given entirely to pineapples and the results of the work were reported in Press Bulletin No. 22.

PROPAGATION INVESTIGATIONS.

Citrus Fruits.

Considerable time has been given to studies in the propagation of citrus. Much difficulty has been experienced by those who have attempted to bud the citrus in Hawaii, and many failures have been reported. Information of similiar failures, even in the work of experienced propagators, has reached us from the Philippines. A careful study was therefore made of prevailing conditions and the difficulties to be overcome. The methods of budding used were those common in citrus culture and known as "shield budding," with a "T" shaped incision; with an inverted "T" and with right-angled and curved incisions. The two latter were used only with angular budwood and the curved incision was adopted only in old bark. While reasonable success can be expected from any of these, it is recommended that those who have difficulty in budding should adopt the ordinary method with the inverted "T." This is described in Bulletin No. 9 of this station, and in all works relating to citrus propagation. The tying may be done with raffia or strips of cotton which have been dipped in melted wax. If the latter are used, they should be held tightly in place by twisting together the ends. These experiments have added nothing new to the knowledge of methods of budding, but have discovered the causes which are believed to be chiefly responsible for the numerous failures reported, and have also afforded opportunities for the testing of remedies, thus point-

ing the way to success. The chief causes of failure are poor bud-wood, lack of vigor in the stocks, and insect attack.

Insects are frequently the sole cause, and the others, only subsidiary; but whatever may be the reason for the lack of vigor, whether it be infertility of soil, insufficiency of moisture, insects, or diseases, it must be removed and a vigorous, healthy condition restored before budding can be successful. Only when there is a comparatively rapid multiplication of cells, can the bud-shields and the stock unite. The bud-wood should be well matured and from a healthy growth. If selected before the most active growth begins, in the spring, it can be preserved in sphagnum moss until wanted. The moss,after being soaked in water, should be wrung out as dry as possible. It will then retain sufficient moisture to prevent the withering of the bud-wood, but will not induce decay. Spread out a thin layer of this moss on a sheet of heavy wrapping paper, place the bud sticks on it and roll up the package. It will be necessary to open the package every two or three weeks and again dip the moss in water. Bud-wood has been kept in excellent condition in spagnum moss at this station for several months.

Insects are the most prolific source of trouble in budding citrus in Hawaii. The work of testing methods of control has been carried on in cooperation with the entomological division of the station. Several species of insects have been very prevalent during the year and have thus afforded good opportunity for studying means of control. Chief among these insects are the following:

Scale insects and mealy-bugs.—A mealy-bug (*Pseudococcus filamentosus*) is prevalent on all species of citrus trees in Hawaii. Not only does it greatly reduce the vitality of the tree, but if an incision is made in the bark of an infested tree, as is done in budding, it is quickly occupied by a new colony of mealy-bugs. These rapidly multiply, cover the bud and destroy it. The young are so minute and so near the color of the bark that the new infestation may not be observed until the colony is well established.

The purple scale and the Florida red scale are also very destructive to citrus trees and if not checked, render budding extremely difficult.

Remedies. The most effective remedy for such scales and mealy-bugs has been fumigation with hydrocyanic acid gas.

In most instances, one treament has been sufficient to rid the tree of the pests (see remarks below, relating to fumigation). Ladybirds, (Coccinellidæ) do much to hold some scale insects in check, but up to the present time, at this station, they have not proved sufficient for the task of holding in control the three species mentioned above to a degree sufficient for the purposes of budding.

Climbing cutworms have been very destructive to many crops on Oahu during the year, and were numerous in the citrus orchards where most of the budding was performed. The damage consists in the devouring of the bark of the bud or budshield, or if this has escaped until the new shoot appears, the latter is girdled or completely cut off. It has not been found difficult to destroy these insects by placing poisoned bran on the surface of the soil about the trees. A small amount is sufficient and the remedy is effective and inexpensive. It consists in the following:—Paris green, ¼ pound, wheat bran, 10 pounds, sugar (brown), 1 pound, water, sufficient to moisten. Mix the Paris green, bran and sugar while dry and add a little water but not enough to prevent crumbling.

Archips postvittanus.—This insect in the larval stage, does much injury by folding the new leaves and also by eating the foliage. The remedy applied has been arsenate of lead in the proportion of 5 pounds to 100 gallons of water.

Aphids.—These are familiar to all as small greyish-black insects, some being winged and inhabiting the youngest growth in such numbers as frequently to cover the branch. They are usually overtaken by their natural enemies, but it sometimes becomes necessary to apply weak solutions of whale oil soap to assist the shoot while young.

Citrus Stocks.

The citrus stocks being tested run in parallel rows and consist of the following:—Rough lemon, sweet orange, shaddocks and seedlings from California grown pomelos. This is about the order also in which they stand at the station in their vigor of growth and their ability to produce growth in the inserted buds. They are so arranged in the orchard that each important variety of orange, lemon, or pomelo is budded on each of these stocks. Plate I shows six months' growth of

a Bahia or Washington Navel orange on a common sweet orange stock.

Seasons for budding.—The budding of the citrus trees was done during January, February, March, and April and appeared to be equally successful in all of these months if the individual trees were in active growth. How much longer it could have been continued, we do not know. The buds set early in the year are, of course, ahead in point of growth.

MANGO PROPAGATION.

The system in vogue in mango propagation, known as "patch-budding," has been practiced for several years. It has been defective as a commercial system because it requires that both the bud-wood and the stock shall be in a condition of rapid growth when the work is being done, and further, because the operation cannot be performed with sufficient rapidity. It was, therefore, sought to devise a method of budding the mango which would be an improvement in these or other particulars. The device that has been adopted consists essentially in the application of shield-budding with the inverted "T", using well matured wood as in patch-budding, and cutting the "T" and the shield very long. The incision is usually made six or seven inches long and the shield, about three or four inches. By this method, budding can be performed when only the stock is in active growth and the work can be done much more rapidly. Full instructions, together with data relating to the histology of the bud-union, are described in Bul. No. 20.

Inarching.—This method of propagating the mango has been, to a large degree, supplanted by budding in the practice of this station. It has been found very useful, however, in dealing with valuable trees that have become pot-bound or otherwise stunted. Mango trees have been received by mail and by freight from long distances. It requires considerable time for these to recover and some have never made a satisfactory growth, even when planted in the orchard with the best of care. The plan has been adopted of inarching a branch of such trees to the trunk of a vigorous seedling, later cutting off the whole top just above the union. For this purpose, the pot is plunged in the soil at the root of the seedling. This aids in maintaining uniform moisture in the pot, and also in plac-

ing the graft low on the stock. On a well established seedling root-system a single branch thus inarched will often make more growth in six or seven months than a whole tree placed in the orchard on its stunted root-system, could make in a year or two. After a month or two, when the inarching process has become complete, the potted tree can be removed to the side of another seedling and a second branch may be grafted. This has been found to be the best use that can be made of new introductions of mangoes.

AVOCADO PROPAGATION.

Some preliminary work has been done in avocado budding to determine the most satisfactory methods and season for such operations.

RECORDS.

The system of records of plantings and of the life history of plants in the horticultural division has been evolved as the needs of the work demanded. The system at present consists of the following:—

1. Accession book.
2. Alphabetical card index.
3. Loose-leaf note books.
4. Maps of fields.
5. Photographs.

In the accession book, as now used, very little is recorded except the date, the name, and the number in its numerical order. This affords a ready reference from any label number. The card index is arranged alphabetically. Here are recorded all the data available at the time of planting, except when a large amount of detail is necessary. In most instances, the card has proved sufficient for the whole record from planting to the present date. In the more elaborate experiments, loose-leaf note books are used and indexed by subject referring also to the accession numbers.

During the year just closed, the four cultivated fields of the station, in which are most of the plantings of the horticultural division, have been carefully surveyed and mapped. The station is greatly obligated to the Survey Department of the Territory of Hawaii for cooperation in this work in the making

of the original surveys and outline maps. Mr. C. J. Hunn, assistant horticulturist, has located all plants and recorded on the maps their position and number. Plate II shows a general view of these four fields, designated as fields A, B, C, and D. Each of these fields is divided into sections running from south to north. The sections are determined either by natural boundaries or by the character of the more permanent plantings; and are designated by Roman numerals. Where necessary, these sections are cut into divisions running throughout the entire length of the section. These divisions are designated by Arabic numerals and are numbered from left to right, as are also the rows. Further subdivision has not been found necessary up to the present time, but can be adopted as required. To illustrate, the index card "*Mangifera indica,* No. 1942" indicates the location of this trees as "C. IV. R. 3. The tree can immediately be located in Field C, Section IV and Row 3. (see Plate III). This field being narrow, no divisions are used. A tree in Field B might be designated "B. II. 2, R. 1. It would be found in Section II, division 2, row 1.

A very convenient use is made of this mapping system in loose-leaf note book records. Certain sections are photographed and the print inserted where needed in the notes. For example in Field C, section IV (see Plate III), which includes the mango orchard, considerable work has been done in budding and inarching on certain trees. It adds much to the convenience and accurracy of records to have a map of this section in the note book.

This mapping has required much time and patient effort at the beginning, but will result in economy of time and in greater accurracy in the making and availability of all records.

DEVELOPMENT OF EXPERIMENTAL ORCHARDS.

There are being developed, for experimental use, citrus, mango, and avocado orchards and also miscellaneous collections of fruit plants. These are already being used for experimental purposes. In connection with the propagation studies a large part of the citrus orchard has been budded to the leading varieties of orange, lemon, pomelo, lime and other species.

The propagation work with mangoes has afforded a similar

opportunity to change part of the seedling plantings into an orchard of varieties of known or reputed merit.

The Use of Hydrocyanic Acid Gas in Orchards.

In cooperation with the entomological division, a test has been made of the adaptability of hydrocyanic acid gas to Hawaiian conditions and of the efficiency of this gas in destroying certain insects not common where fumigation methods have been most carefully worked out.

The remedy has been found so effective in destroying the mealy-bug on citrus trees, *Pseudococcus filamentosus;* and the avocado mealy-bug, *Pseudoccus nipae,* as well as the Florida red scale, and the purple scale which have long been held in check by this means in the citrus belt of the mainland, that it has been adopted in orchard treatment at the station to the exclusion of oil sprays whenever the work of the natural enemies available proves insufficient for the task. The *P. filamentosus* is the more difficult to kill, because of its very heavy covering of cotton-like filaments; but when fumigated while the trees have no new growth, even the eggs of this insect have been destroyed without injury to the foliage. It is necessary to remove a few inches of soil from the crown so as to expose to the gas, the insects on this part of the tree.

COVER CROPS.

The use of cover crops in the station orchards during the rainy season has become an established practice. Only the jack bean and cowpea of the clay type have been used during the year as cover crops since these proved best adapted to the purpose of any legumes tested in earlier trials. The cowpea is a rapidly maturing crop, furnishing a large amount of green manuring and remaining green as long as necessary for the average rainy season. If the wet weather should be prolonged, the cowpea might pass the stage of best growth for green manuring before it would be safe to open the ground to the washing of rains. The seeds were planted in Field C on January 2 and 4, the rainy season having apparently begun. The first flowering was observed March 17, and the crop was plowed under April 20 and 21.

The cowpea is very subject to the attacks of a species of aphid (*Aphis medicaginis*) and if the natural enemies of the latter are not present, the whole crop may be destroyed. A severe attack of aphids occurred in the plantings referred to above, and for several weeks the plants made practically no progress. Later, six or seven species of ladybirds (Coccinellidæ), multiplied rapidly and completely overcame the aphids, so that early in March the plants were again in vigorous growth and very rapidly covered the ground. These experiences give rise to two practical suggestions. If cowpeas are to be used as a cover crop during the seasons when aphids are most abundant, the grower should see that colonies of the beneficial insects are at hand. Cowpeas may be used as a means of multiplying ladybirds of the six or seven commonest species in Hawaii, if the plantings are not in the neighborhood of valuable trees or plants which are also subject to attacks of aphids.

Jack beans do not come to maturity so rapidly as cowpeas and may be used where it is desired to keep the ground covered longer. They are also less subject to the attacks of aphids.

The pigeon pea (*Cajanus indicus*), has proved a valuable leguminous plant, but its growth is so tall and also so woody that it becomes difficult to cover.

A number of other legumes are being tested in plats and some of the more promising of these may be tried under orchard conditions.

WIND-BREAKS FOR ORCHARDS.

A wind-break has been planted about Fields B and C. This consists of a row of *Eucalyptus robusta* on the outside, and a row of Monterey cypress (*Cupressus macrocarpa*) within. The trees in each row are about eight feet apart and the Monterey cypress stand opposite the open space between the Eucalyptus. By these two species, the Eucalyptus running rapidly upwards, and the cypress being of dense growth near the ground, it is expected to provide an effective wind-break.

VEGETABLES AND SMALL FRUITS.

Mr. C. J. Hunn, assistant horticulturist, has under way a number of experiments with vegetables, muskmelons, and the

roselle. A test of quite a large number of varieties of tomatoes is being made with a view to determining, among other things, their varying degrees of resistence to the melon fly. An attempt is being made to grow muskmelons under a cheese-cloth covering to protect them from the melon fly.

A trial is being made of the "Mercedes" type of sweet potato in comparison with a few local varieties. It is this type which is being almost universally found in the Pacific Coast markets, which Hawaii should supply during the spring and early summer months. It may prove best to introduce our own varieties in these markets.

The culture of the roselle has been continued and some tests have been made in drying this fruit. Mr. Hunn submits the following data on the subject:

"A number of queries concerning the advisability of drying the roselle, thus making it less bulky for, and less susceptible to decay during shipment, have come to the attention of the horticultural staff. Accordingly, a number of experiments were undertaken to ascertain the advisability of drying the roselle, dealing almost exclusively with the calyx of the plant, since this is the portion generally used in jam or jelly making.

"Three separate experiments were conducted in drying the roselle, the first two being with the Porto Rican strain, and the third, with the Victor variety. The first lot was picked November 24, 1908—36 weeks from sowing; the second lot, on December 8,—38 weeks from sowing; and the third, on December 8, 1908,—36 weeks from sowing. The first lot was placed out of doors for drying on November 26, 1908, and kept in the open as much as possible, being removed to a dry building at night, and at other times because of the frequent rains which are so prevalent at this time of the year, and which would seriously interfere with the ultimate results of drying. The fruits were placed in shallow slatted flats with cotton cheese cloth spread over the bottom to prevent loss through the slats. When sufficiently sun dried, the flats were stacked in a dry airy exposure to finish curing.

"The results of the drying experiments are as follows:—The portion eliminated before drying equals 32 per cent, leaving 68 per cent, which is the total weight of the calyces to be dried. The calyces in drying shrank to 8.8 per cent of the total

weight of the fresh fruit, or lost, in drying, moisture equal to 7.7 times its weight. Consequently, one pound of the dried calyces is equal to 8.7 pounds of the fresh calyces, or to 12.8 pounds of the fresh fruit.

"If fresh roselle sells at four cents per pound, in order to make an equal profit from the dried calyces, it should sell at about forty-five cents per pound, plus the cost of drying. In drying the roselle such items as severing the calyces and the seed pod by cutting, separating the calyces from the seed pod after cutting, boxes, the moving and the care of the fruit during drying and storage must also be considered. From figures obtained from companies who are interested in the production of jellies and preserves, we ascertain that they are not willing to pay such a price for the dried roselle and offer less than one-half.

"It is apparent that the rational and profitable method of marketing Hawaiian roselle is in the form of jams and jellies, manufactured here, thus avoiding the cost of drying. It is also probable that the fresh fruit will make a finer manufactured product than the dried article."

THE HORTICULTURAL STAFF.

The horticultural staff has been augmented by the appointment in June of Mr. Valentine Holt, a part of whose time is being devoted to horticultural work. Mr. Holt has collected and prepared an exhibit of a large number of fruits and other products now being shown at the Alaskan-Yukon-Pacific Exposition. He has begun work in the selecting and propagation of varieties of papayas with a view of systematic breeding.

MISCELLANEOUS NOTES.

The horticulturist again visited the deciduous orchards planted in recent years at the Parker Ranch on Hawaii and advised in matters of pruning and general care, also noting the progress of the orchards which give every promise of success.

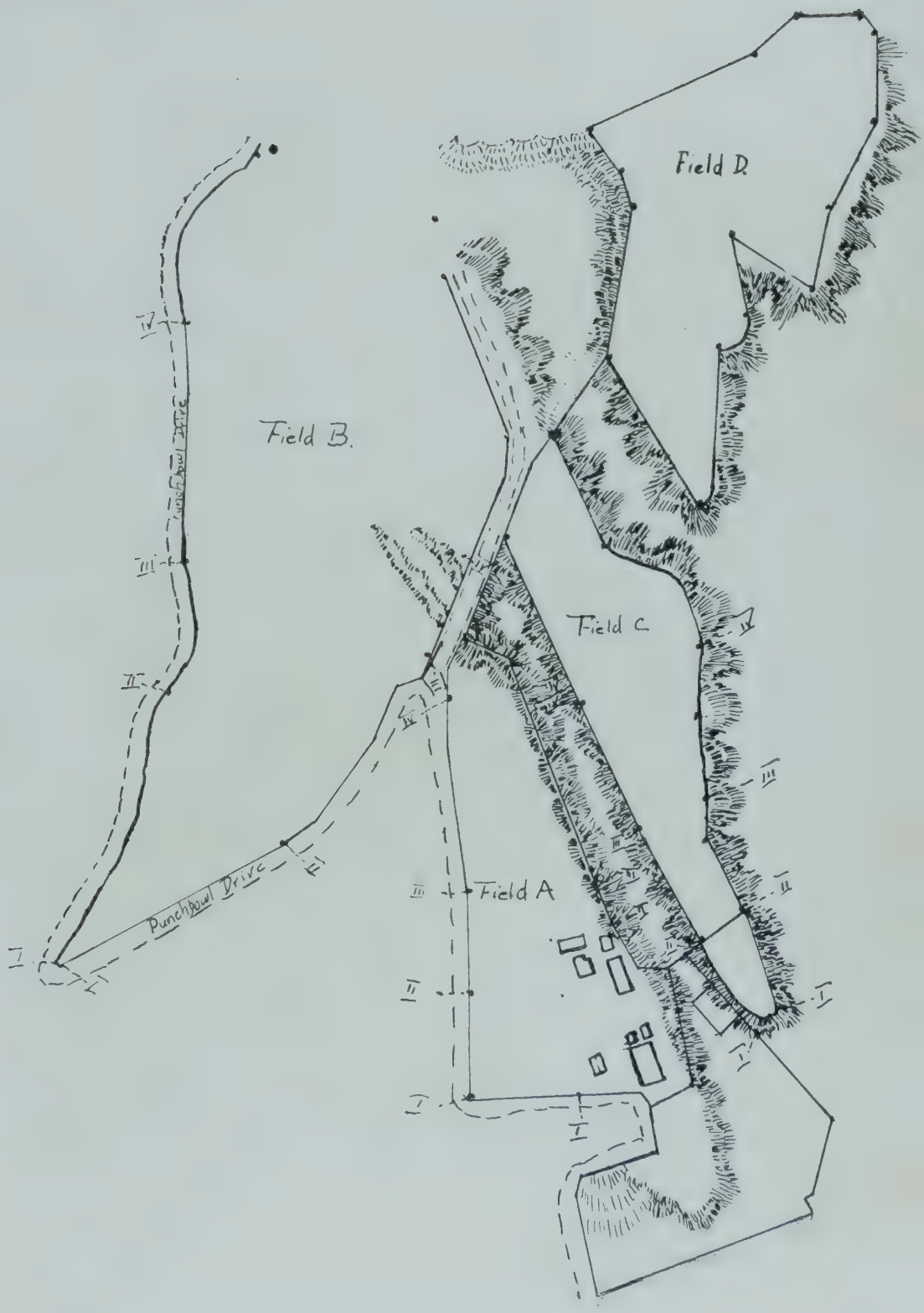
The three varieties of litchi, introduced in June, 1908, have made a good growth during the year. These varieties are No mi chi, Kwai mi and Hak ip.

Carissa arduina, S. P. I. No. 11,734. This South African

PLATE I

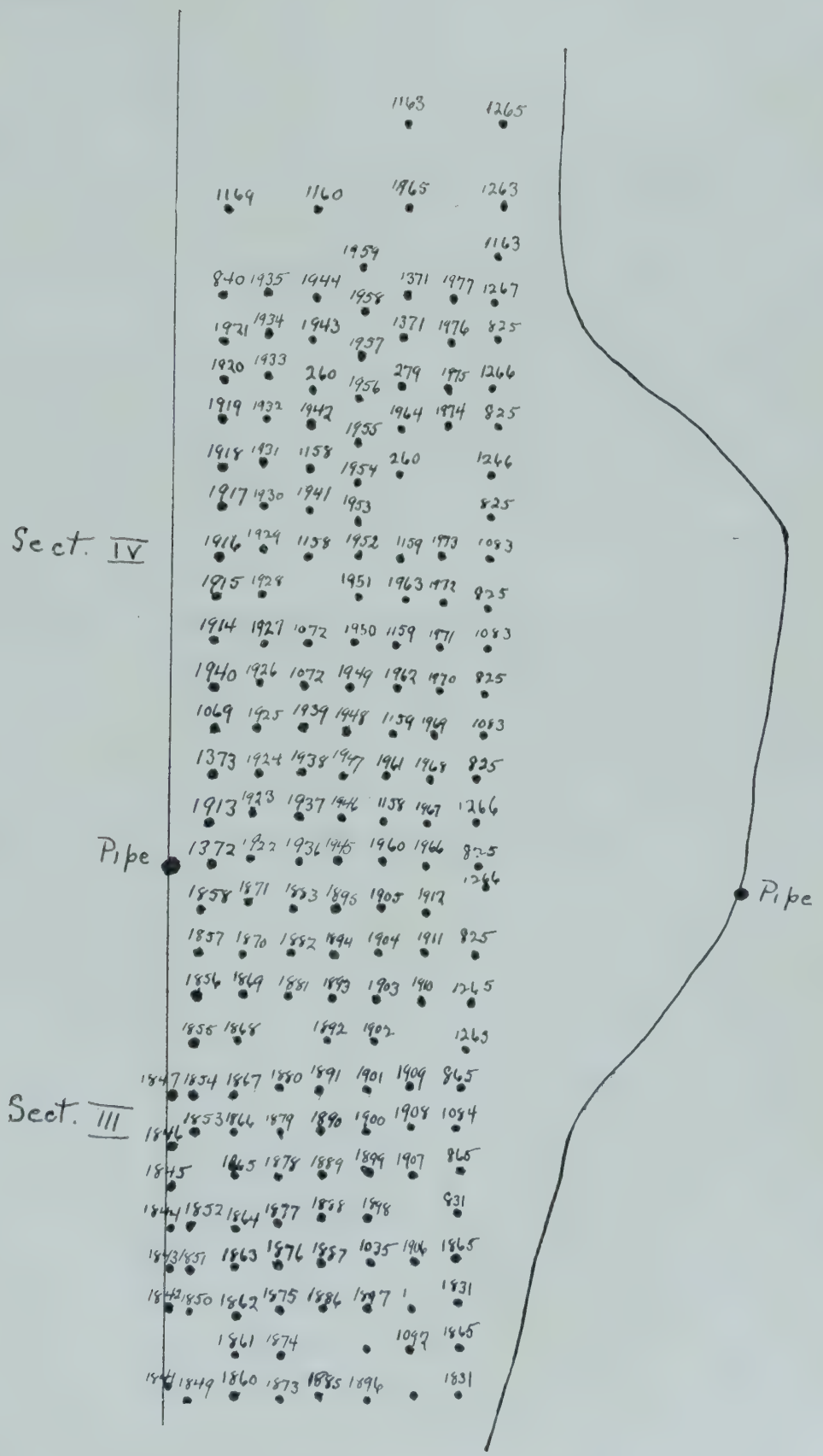
BAHIA NAVEL ORANGE ON COMMON SWEET ORANGE STOCK, 6 MONTHS' GROWTH FROM BUD.

PLATE II.



GENERAL VIEW OF FOUR CULTIVATED FIELDS.

PLATE III.



FIELD C, SHOWING LOCATION OF TREES.

fruit and hedge plant has fruited at the station in the past few months. It has made a strong growth. This, together with its glossy green foliage, its white star-shaped flowers and its bright red fruits, renders it an attractive hedge plant. It is armed with quite heavy thorns. The fruits are edible and have been appreciated by many of those who have tried them at the station. The species is being further propagated.

The Eden pineapple has fruited for the first time at the station. The other hybrid pineapples are now making a good growth but none have produced fruit.

Coleococcus amicarum. Through the kindness of Mr. W. S. Lyon, of Manila, a successful introduction was made of this economic plant. The five plants have been planted out.

Rattan palm, *Calamus* sp. (Dæmonorops). Through Mr. H. P. Wood, Secretary of the Hawaii Promotion Committee, two introductions of seeds of rattan palm have been made from Java. A large percentage of these have germinated and are doing well.

REPORT OF THE CHEMIST

By W. P. Kelley

The work of the chemical department during the past year has been devoted to the following lines of investigation: A study of the pineapple soils of Oahu; an investigation of the fertilization and nutrition of rice; fertilizer experiments with cotton; and miscellaneous.

PINEAPPLE SOILS.

The pineapple soils throughout the islands are, for the most part, located above the cane lands at elevation of from 600 to 1,000 feet. At least two-thirds of the land devoted to this crop is situated on the upland plain between the Koolau and Waianae mountain ranges of Oahu. This section is subjected to extremely variable climatic conditions, especially as regards rainfall. Some months a very heavy precipitation, to the extent of 10 or more inches, followed by a very dry period, produces in the soil wide variations. From the very beginning of this industry it has been the practice to grow pineapples continuously on the same land with little or no rotation of crops: although some of the growers fallow their land one or two years out of every five. In many instances the farmers, on account of the presence of various insects, have been induced to burn or remove from the land every vestige of the old plant before preparing for a new crop; and while it is true that the fruit alone does not make very heavy drafts on the soil, any single crop system, coupled with the burning or removing of plant residues, is an exhaustive one, and one that is likely to produce ill consequences.

Even if the ash of the old plants be left on the soil, thus returning to the land the minerals taken from it in the growth of the previous crop this practice robs the soil of the nitrogen which the previous crop consumed. Not only is the soil in this way robbed of its nitrogen, but any humus, which the organic matter is capable of producing, is also destroyed. The active forces that predominate in these soils at the high temperatures,

which prevail throughout a large part of the year, bring about a rapid oxidation of the organic matter in the soil; and any system that involves removing from this land the organic matter produced thereon without the growing of green-manuring crops or the application of humus-producing manures, leads to bad physical, chemical, and biological conditions in the soil.

Furthermore, these soils contain large amounts of finely divided ferric hydrate, which becomes gelatinous when wet, and has a high water-holding power.[1] During the periods of heavy rainfall the soil becomes saturated with water, and in consequence of its fine state of division, large percentage of ferric hydrate, etc., the water is held tenaciously. Organic matter, on the other hand, would tend to make the land more porous and thus bring about better drainage.

The growers have observed from the outset that the soils in this section naturally fall into two classifications as regards color,—black and red soils. Influenced by the fact that black soils are almost universally regarded as rich soils, the prospective growers, at the begining of this industry, eagerly sought the soils of dark color. But it has been found subsequently that the red soils are naturally better adapted to pineapples than these black lands. Usually the plants present a peculiar appearance on the black soils, and do not grow as successfully as on the red land. The fruit on the black soil is characterized by a whitish-pink color, lack of flavor and an excess of acidity. The red soils, while producing large yields of excellent fruit at the beginning, yield diminished harvests with each subsequent planting. These practical difficulties have brought about a demand on the station for assistance in the way of analyses of soil samples and for advice in regard to the use and selection of fertilizers.

Recognizing the importance of this crop, and the need of scientific information as regards these soils and their fertilization and management, the station has undertaken an extensive investigation of the questions involved. After some preliminary investigations and a general study of the conditions and practices in the three principal areas of this island, a series of forty fertilizer plat experiments was begun on the red and black soils, respectively, and in each instance, on land that had previously produced two or more crops of pines. The principal objects in

1 Soils, by Hilgard, p. 196.

making these experiments were to determine the fertilizer requirements of pineapples on each of these types of soil; and to ascertain whether or not it is possible, by the use of fertilizers, to maintain the original yields of fruit. On the black soil it was hoped to find some practical means of overcoming the yellow color of the plants. The red soil experiment is located on the land of the Hawaiian Pineapple Company at Wahiawa, and after thorough tillage and good preparation, fertilizers were applied and pineapple plants transplanted on September 8, 1908. The black soil experiment is located on lands of the Wahiawa Consolidated Pineapple Company, the fertilizer being applied and the crop transplanted on September 19.

About eighteen months is required from the time of planting until the first harvest, and therefore, it is too soon to draw final conclusions in regard to the relative officiency of various fertilizers used in the experiments. But without attempting to discuss these in detail, it may be said that certain combinations of fertilizing substances are producing thrift and vigor, whereas others are not proving so effective.

At this time, however, the author wishes to further emphasize the importance of the very best possible drainage for pineapples, especially on the red soils. The fertilizer experiments on the red soil are located on a gentle incline, but unfortunately, the rows on part of this experiment run at right angles to the direction of natural water flow; and although open ditches are maintained every thirteenth row, that is about fifty feet apart, the drainage on this part of the experiment has not been effective. Furthermore, the same combinations of fertilizing substances that are producing good effects on the better drained portion of the experiment, are not producing similiar effects on the more poorly drained portion. Various applications of different fertilizers to this red soil by the growers have often given promise of good harvests, but it frequently develops at some period in the growth of the crop that there is something else lacking in the soil besides available plant food. Often the plants grow satisfactorily some months after planting, especially if this happens to be during a period of comparatively light precipitation, but later it is observed that there are scattering plants, or sometimes spots of considerable size on which the plants are not growing well. These appear to be stunted, often

reddish-yellow in color around the outer edges of the leaves; and upon pulling up such plants, it is found that the roots are dead and the whole underground part of the plant is water-soaked, sometimes fermenting and half rotten. Such conditions seem to be most frequent and make their first appearance following a period of continued rains or a deluge. In several authentic cases, a heavy downpour caused an overflow of ditches, and consequently a flooding of the land, and in the course of a few days the plants on the flooded areas showed just the appearance pointed out above. Even here the water could not stand above the surface because of its rolling topography, but there was brought about such a saturated condition of the soil that, on account of its high water-holding capacity, due to its high percentage of ferric hydrate, and low humus content, aeration was largely shut off; and stagnation ensued, a condition which the pineapple plant will not tolerate.

During the continued dry weather of last fall, the author found that wherever water had flowed over the soil or the soil had been previously saturated, the plants were not thrifty, and in many instances had died. In such places it was almost impossible to force a spade into the soil, so compact and dry had it become. The incorporation of organic matter in this soil will undoubtedly increase its aeration by enlarging the air spaces and would prevent a serious compacting of the soil and bring about a more uniform distribution of soil moisture; thus effectually preventing stagnation during the time of rains and enabling the soil to hold an optimum of water for a much longer period after rains and at the same time greatly lessening the tendency of the soil to become dry and hard during periods of rapid evaporation. An excess of stagnant water also brings about a bad biological condition, and in soils like these, which contain a relatively large percentage of ferrous oxid, a saturated condition contributes to the formation of considerable amounts of ferrous carbonate and ferrous sulphate, bodies which are known to be plant poisons. In addition, nitrification is seriously interfered with, and possibly the solubility of certain minerals is changed.

In connection with the field experiments, a laboratory study of these soils has also been undertaken. A large number of samples of each type of soil has been analyzed, and some extremely interesting and abnormal conditions have been found.

The following table fairly represents the chemical composition of each of these types of soil:

Table showing water-free composision of some pineapple soils.

	RED					
	SOIL	SUBSOIL	SOIL	SUBSOIL	SOIL	SUBSOIL
	Laboratory No. 5	Laboratory No. 6	Laboratory No. 7	Laboratory No. 8	Laboratory No. 13	Laboratory No. 14
Insoluble matter	43.79	38.64	40.89	39.25	46.52	46.37
Potash (K_2O)	.62	.73	.51	.60	.50	.57
Soda (Na_2O)	.20	.30	.21	.32	.31	.13
Lime (CaO)	.46	.46	.51	.66	.32	.31
Magnesia (MgO)	.41	.35	.37	.38	.40	.42
Iron (Fe_2O_3)	26.11	32.54	35.72	33 28	24.37	24.49
Alumina (Al_2O_3)	10.82	10.45	3.58	8 66	9.15	12.02
Manganese (Mn_3O_4)	.27	.19	.22	.06	.33	.35
Phosphoric acid (P_2O_5)	.13	.16	.07	.08	.09	.13
Sulphur (SO_3)	.08	.04	.09	.07	.11	.12
Volatile matter	13.73	14.06	14.22	13.99	15.98	13.17
Total	100.15	100.60	100.22	100.09	100.28	100.13
Nitrogen (N)	.24	.22	.34	.25	.38	.25
Acidity[a]	1960.00		1568.00		392.00	

	BLACK					
	SOIL	SUBSOIL	SOIL	SUBSOIL	SOIL	SUBSOIL
	Laboratory No. 9	Laboratory No. 10	Laboratory No. 11	Laboratory No. 12	Laboratory No. 15	Laboratory No. 16
Insoluble matter	33.45	36.06	39.02	42.60	33.73	34.53
Potash (K_2O)	.83	.74	.78	.81	.99	1.07
Soda (Na_2O)	.40	.42	.36	.44	.21	.38
Lime (CaO)	1.39	.86	.64	.60	.49	.37
Magnesia (MgO)	.54	.43	.41	.39	.52	.41
Iron (Fe_2O_3)	19.65	21.51	18.24	20.52	26.03	26.85
Alumina (Al_2O_3)	15.50	15.74	15.40	16.89	15.82	18.98
Manganese (Mn_3O_4)	9.74	8.76	4.80	3.50	4.01	2.43
Phosphoric acid (P_2O_5)	.21	.16	.36	.13	.35	.21
Sulphur (SO_3)	.16	.09	.23	.05	.17	.05
Volatile matter	17.73	14.45	19.71	13.72	16.68	12.83
Total	100.33	100.31	100.35	100.23	99.85	99.79
Nitrogen (N)	.39	.23	.45	.19	.35	.20
Acidity[a]	neutral		196.00		98.00	

[a]Calculated to pounds CaO per acre foot.

The above table shows that the two types of soil differ materially in but one point, namely, as regards their respect-

ive manganese content. Since determining that the black soil contains such large percentages of manganese, a thorough investigation of the entire pineapple section has resulted in establishing that all the black soils in this section contain relatively large percentages of manganese; and that there is a close correlation between the manganese content of these soils and the general appearance of the pines. It is not deemed necessary at this time to go into a detailed discussion of this work since a preliminary report has already been issued [1] and the investigation is still under way. It may be said, however, that the manganese in this soil is in an extremely soluble form, even more soluble in weak solvents than any, or all, of the other constituents of the soil combined. It appears that the form of manganese is influenced by the growth of pines, in that it is changed into a higher state of oxidation; and furthermore, such change is detrimental to the growth of the plant. Plants grown on manganese soil are found to contain a higher percentage of manganese than those grown on the red soil, and to possess a markedly different oxidizing power as measured by the rate at which water extracts of the plant change the color of alcoholic solution of guaiacum, etc. This investigation is being continued with a view of determining what influence manganese has upon other constituents of the soil, their solubility, etc., its effects on nitrification and the physics of the soil. A detailed study of the absorption of nutrients of the pineapple plant at the various stages of its growth, on both types of soil, is also being undertaken. Soils of similiar somposition are very rare, and it has been deemed wise to make a study of manganese in its relations to plant growth in general, since here we have an opportunity of studying the effects of this element under natural conditions.

RICE INVESTIGATIONS.

For some years this station has been investigating the rice industry in these islands, reports of which work may be found in the Annual Reports for 1907 and 1908; and in these, the importance of this crop and some of its economic phases have been emphasized. Several fertilizer tests have been made and

1 Hawaii Sta. Press. Bul. No. 23.

the relative practical economy of various fertilizers has been pointed out. In consideration of the importance of this crop, the conditions under which it is grown, and the old established oriental practices of fertilization, which prevail in rice culture here, and that chemical fertilizers are generally applied when the crop is two-thirds grown, it has been deemed wise to devote some time to a study of some of the more fundamental questions regarding the absorption of nutrients by the rice plant, etc. When it is considered that rice is grown in submerged culture, and therefore variations in composition due to variations in available water supply, are eliminated, it is at once apparent that this crop readily lends itself to fertilization investigations.

Accordingly, in January, 1909, in conjunction with the agronomist, this department instituted a series of fertilizer plat experiments on the rice trial grounds of the station. The object of these experiments is not only to determine the efficiency of various fertilizers, as measured by increased yields of paddy and straw, but to determine at what period in the growth of the rice plant the various nutrients are absorbed, and some of their inter-relations and functions. In these investigations samples from the several plats have been taken at different periods in the growth of the plant. These were separated into their botanical parts and a chemical analysis of each is being made. The cultural part of the work is being done by the agronomist. This work is now in progress and will probably not be completed for some months, since it is hoped to duplicate the experiment with a spring and fall crop. Results of scientific interest, have, however, already been obtained, as for instance, the rice from the plats, which receive certain fertilizers, has been found to have a materially different composition, as regards the nitrogen content, from those without fertilizer. The large amount of analytical work, involved in such an investigation, necessarily prolongs the time of completion; but it is hoped that the data may be ready for publication during the present fiscal year.

FERTILIZER EXPERIMENT WITH COTTON, AND MISCELLANEOUS.

The growing interest in cotton, as a new industry in Hawaii, is sufficient justification for an investigation of every agricultural phase of this crop, and with the knowledge of the import-

ance of fertilization of sugar-cane the prospective cotton growers naturally desire information in regard to the fertilization of this crop. Consequently, in February, 1909, a series of fertilizer plats was laid out on each of the two extensive cotton experiments referred to in this report by the agronomist. It is entirely too soon to draw conclusions from these experiments further than to point out that on each of the experiments it is already apparent that the application of phosphates has greatly increased the growth of the plants.

A small amount of miscellaneous analytical work has been done, such as the analysis of an occasional sample of water, fertilizer, soil, etc.; but it is the policy of this department to confine its efforts, as largely as possible, to a few lines of research, and only in so far as it is necessary in the cooperation of other departments, will miscellaneous work be accepted.

REPORT OF THE AGRONOMIST

By F. G. Krauss.

Rice and cotton investigations continue to be the main lines of work of this division. The rice expriments were begun in 1906, and the cotton work in the early spring of 1908. As a part of these investigations, considerable attention has been given to the testing of field crops with a view to developing cultures suitable for rotation with rice and cotton, and if possible, adapting some of the crops to green manuring. It is recognized that the permanent conservation and upbuilding of our soils is as important as to increase immediate production, and a rational system of crop rotation, together with practical schemes for green manuring are important practices looking to that end. Constant effort is being made to encourage cooperative field experiments with planters, and the past year has seen greater strides in this direction than ever before.

RICE EXPERIMENTS.

The work with rice consists of testing new varieties and the development of pure strains of the best types; experiments to determine the best methods of culture; and fertilizer experiments, together with the testing of crops suitable for rotation or substitution.

The problems affecting the artificial fertilization of the rice crop continue to receive much attention and the results of the work have already aided growers materially in increasing their yields. However, it is recognized that to be of greatest permanent value, work of a more fundamental nature is necessary. Accordingly, in January, the chemist and agronomist planned a series of experiments looking to that end. The cultural end of the investigation has been undertaken by the writer and the chemical work by the chemist.

CO-OPERATIVE FERTILIZER EXPERIMENTS.

Based on the results obtained in a previous experiment,[1] the Palama Rice Plantation on Oahu, consisting of approximately 100 acres, which had not previously used chemical fertilizers, undertook in the spring of this year, under the station's direction, the use of some eighteen tons of a high-grade complete fertilizer of the following composition:

6 per cent nitrogen (3 per cent organic, as fish guano, 3 per cent as sulphate of ammonia).

9 per cent phosphoric acid (4 per cent as water-soluble, 5 per cent as reverted).

10 per cent potash as sulphate of potash. The net cost of the fertilizer was $870.00, or $8.70 per acre. To this should be added transportation and cost of application, which would bring up the cost to approximately $10.00 per acre.

A careful survey of the entire plantation, in company with the proprietor, during April and May indicated that the general fertilization was very effective on all the lands except those near the sea. On May 1st, when the crop was well headed out, the total yield of paddy was estimated at 180 tons as against 131 tons for the previous spring crop.

On May 20, a few days before the beginning of the harvest, a visit was made to the plantation preparatory to making the test weighings. The first field inspected showed the work of a destructive army worm (*Leucania unipuncta*), the full extent of the damage becoming more and more apparent as the inspection progressed. The aid of the station entomologist was called in, and it was soon found that the scourge was prevailing over a wide extent of the rice territory, both on Oahu and Kauai. The damage had been done quickly and was over almost before any one was aware of the pest. This attack of an insect pest on rice was absolutely without precedent in the Hawaii industry. A full report upon the pest will be found in the report of the entomologist.

The total ultimate yield of the crop was 104½ tons of paddy, the smallest crop ever recorded for this plantation, and this, under conditions otherwise the most promising in its history. Some idea of the destructiveness of the caterpillar may

---

1 Cooperative Experiments, Hawaii Sta. Rpt., 1908.

be obtained from the fact that one field, consisting of twelve acres, yielded only 11,015 pounds of paddy against 35,000 pounds, harvested the previous season. This was one of the best fields and the first patch to be attacked.

Within the above area a fertilizer experiment, covering 2½ acres, was under way at the time of destruction, so that no more reliable data could be obtained from it than from the general fertilization.

Below are given the yields of the spring and fall crops of the Palama Rice Plantation during the past five years, which may serve to give some insight into the production end of the industry under favorable general conditions and careful management.

YIELDS OF PADDY (STANDARD HAWAIIAN RICE), FROM A 100 ACRE PLANTATION FAVORABLY LOCATED AND CAREFULLY MANAGED.

Year	*Spring Crop.*	*Fall Crop.*
	Pounds.	*Pounds.*
1905	335,708	417,680
1906	262,335	353,469
1907	346,434	359,093
1908	256,300	370,168
1909 [1]	209,366	.....

TESTING AND DEVELOPING NEW VARIETIES OF RICE.

Since the beginning of the rice investigations in 1906, the testing and developing of old and new rice varieties has formed an important part of the work of this division. Up to the present time 166 varieties have been tested in comparison with each other, and as to their adaptability for spring or fall culture. The more promising varieties have been grown for from two to six generations. During the past year, as heretofore, the agronomist personally selected a large number of individual rice panicles from among the growing crops of the leading plantations for breeding purposes. The principal growers were also invited to make selections according to their own ideal

[1] Low yield due to unprecedented destruction by army worm.

type. These were further gone over in the laboratory and the best selections propagated with a view to establishing pure strains.

Rice No. 19 (S. P. I. No. 12508) introduced in the fall of 1907, is now believed to be firmly established. Its bad mixture with other types, due to careless harvesting, has been remedied by the propagation of 10,000 seedlings individually during the past fall. The seedlings were set 10 by 10 inches apart and carefully rogued. The yield from a fifth of an acre was 704 pounds pure seed. The entire amount has been distributed among growers in lots of 50 to 100 pounds, sufficient to plant 2½ to 5 acres, if the seed is carefully conserved. It is hoped that fully 50 acres will be planted for the fall crop of 1909.

The difficulty in milling this rice economically, appears to have been overcome by one of the Chinese millers who reports that by thoroughly drying the paddy, setting the millstones far apart, and running them rather more slowly than is the usual practice, he has avoided the high percentage of breakage hitherto experienced. A very satisfactory sample was turned out during the past season and one grower marketed 100 bags at a satisfactory price.

As in the past considerable upland rice seed has been distributed in the hope that this grain would find favor as a cured fodder for horses. No extensive planting has as yet been reported. In a cooperative experiment at the Kunia lands, on Oahu, where the rainfall is very light, a small planting of the two most promising varieties, Nos. 65 and 68, has given promise of being well suited for culture on large areas now devoted to pasture. If the present high price of imported hay continues, there can be but little doubt that the growing of this crop will prove profitable.

COTTON EXPERIMENTS.

These experiments were begun in the spring of 1908 and were briefly reported upon in the annual report for that year. In March of the present year the experimental data to date were reported in Press Bulletin No. 24, entitled "Preliminary Report on Cotton Experiments."

In January of the presence year a collection of thirty varieties and selections of cotton, representing four more or less

distinct types, were planted for comparative test of yield, quality of lint and habits of growth. Considerable attention is being given to the selection of superior individual specimens, with a view to obtaining desirable mother plants from which to breed pure strains. The importance of the new methods devised for the propagation of cottons, i. e., by cuttings or budding, whereby all the qualities of a given individual plant may be perpetuated indefinitely, becomes more and more apparent as the work progresses. A brief review of methods and results will be found below. Pruning experiments, as applied to plants entering their second season of growth, are likewise under way and will be reported upon more fully at the end of the present harvest.

It may be said at this time, that the Sea Island types respond best to low pruing, i. e., when a mere stump, three to six inches in length, is left . Pruning to tall canes, 15 to 30 inches long, resulted in considerable "die back," the basal shoots almost invariably exceeding the growth from terminal buds. A further advantage in low pruning, which should not be lost sight of, is the fact that the entire removal of the old wood, with its adhering trash, destroys possible insect infestation, which might cause trouble with the new crop. In fact, this phase of growing cotton as a perennial is the most objectionable that has as yet been advanced. In the case of the Caravonica types of cotton, cutting back from one to three fourths of the previous season's growth, appears to give the best results. Being of exceedingly rank growth, too severe pruning causes excessive wood growth at the expense of fruit, and furthermore, such rank growth is extremely brittle. This causes bad splintering in heavy winds. When it is remembered that the Caravonica cottons give their lowest yields during the first year after planting, while the Sea Island apparently give their greatest, or at least optimum yields the first season, some good reasons for the practices outlined become apparent. In the case of the upland cottons, low pruning insured a larger percentage of plants being carried over into the next season than high pruning, but when the plant survived pruning to spurs, similar to the methods adopted by the California grape growers, such plants greatly outyielded the low pruned. However, since only a small number of specimens were available for the pruning experiment, it is

possible that the heavy fruiting plants were naturally more vigorous to begin with. Plate IV illustrates the different systems of pruning described above.

Attention has already been called to the more vigorous growth of the Caravonica cottons over other varieties thus far grown. To this characteristic is laid its late fruiting, and as frequently happens, its shyness to bear fruit,—the two objections that have been advanced against this variety. In digging up a number of plants, it was found that they possessed exceptionally prominent tap-roots, and also strong lateral root systems compared with other varieties. In one striking case, and several lesser ones, it was found that transplanting both hastened and made more profuse the subsequent fruiting.

Growing Cotton from Cuttings.

Plate V illustrates the total cuttings made from a single first season plant, which, in this instance, produced 36 soft-wood, or tip cuttings; and 31 hard-wood, or butt cuttings. The former averaged about eight inches in length, and the latter, twelve inches. It is frequently possible to obtain a hundred or more cuttings from a single Caravonica plant.

The general character of the cuttings is shown in the lower illustration of the plate.

Plate VI illustrates the relative growth of good average Caravonica cuttings. The growth, while not equal to that obtained from seed propagation, is quite satisfactory and likely to be improved as the method is perfected. The plant shown in figure 2, began producing "squares" when less than five months old, which is considerably earlier than seedlings bear; but this cannot be said to be desirable if the ultimate yield is affected, which seems probable.

Budding Cotton.

So far as the writer is able to ascertain, the credit for the first practical demonstration of budding, as applied to the cotton plant, is due Mr. E. C. Smith of Pearl City who, with Mr. E. W. Jordan, are pioneers in the culture of Caravonica cotton. In the fall of 1908, Mr. Smith successfully budded one Caravonica into the stock of another cotton of the same variety.

Six buds were inserted in a ten-months-old tree in November and the illustrations in Plate VII show the plant during the following July. The small figures, 1-6, in figures 2 and 3, show the points of budding. Figure 1 shows the tree before pruning, and figure 3, after the tree was pruned. Up to the time of pruning, when the harvest was practically over, this plant bore 90 mature bolls, producing 15 ounces of seed cotton. Figure 4 illustrates the prunings from which the cuttings illustrated in Plate V were made.

The method used was that commonly termed "shield-budding." The method is simple, rapid and effective, so that its application in field culture is eminently practicable.

Grafting has not yet been attempted and seems to offer no particular advantages, except, perhaps, in the case of old trees, such as are now growing on the station grounds. In this case the cleft-graft would seem the best suited.

General Cultural Notes.

While the cotton experiments are now only in their second year, several important general principles appear to be fairly established as essential factors in the culture of cotton in Hawaii, as based on personal observations and experiment.

Soils and Locations.—Deep, well drained, silty loam soils, on the leeward side of Oahu, and from sea level up to 750 feet elevation, appear to be well suited to the culture of cottons generally, without the aid of irrigation, in seasons of normal rainfall, from 20 to 30 inches per annum.

The dry, broken coral lands, skirting Oahu from Honolulu to Sisal, would also appear well suited to cotton, the E. C. Smith experimental patch of Caravonica cottons being a fine example of possibilities in this region.

The sandy low lands and lower slopes of a large area in the Koolau district of Oahu would seem well suited to Sea Island cotton, judging from samples received from that locality.

A twenty-five acre field of Caravonica cotton located at Makaweli, Kauai, gives great promise in the possibilities of cotton growing in that region without the aid of irrigation.

With the exception of sisal, and possibly pineapples, cotton would appear to be as drougth resistant as any crop now grown

in Hawaii; and it is believed that the crop can be grown successfully over a wide area without irrigation.

Tillage.—The importance of deep and thorough tillage has been well demonstrated during the present summer, as well as last year. A fine example of what deep plowing and constant surface cultivation will accomplish, is demonstrated on the Kunia lands, where with only 24 inches of rainfall during the 12 months preceding June 30, a perfect growth has been maintained up to the present time, and the crop promises a large yield. The same is true of the Makaweli experiment. Twenty-five acres are involved in each of these experiments. At the trial grounds, in a dry, gravelly soil, ample moisture has been maintianed to bring a large crop to maturity by thorough surface tillage, preceded by a deep plowing, preparatory to planting. At the station grounds, where cultivation was curtailed on account of interference of the unpruned plants entering their second year's growth, the plants have suffered for the want of moisture.

Varieties.

No question is more often asked than the suitability of different varieties. The question is a hard one to answer at this time. From a cultural standpoint, it may be said in general, that the Caravonica type is the most drought resistant when once established. In well prepared land it sends its prominent tap-root down deeply into the soil. On the thin coral soils, and the compacted substrata at the station grounds, this variety shows physiological qualities that appear to make it less subject to drought than the Sea Island types. As a perennial plant, in localities with long rainless summers, there can be no doubt as to its adaptability. Sea Island cotton will make a good crop with a very moderate amount of moisture, but requires intensive tillage. Dry weather hastens maturity, but excessive moisture produces rankness of growth. It is believed that the low lands, bordering the sea, are best adapted to this variety. The best samples and largest proportionate yield were obtained in Haunla, and it is believed that the windward district of Oahu is generally adapted to Sea Island, while the leeward district is better adapted to the Caravonica and upland types.

Sufficient experimental data are not yet at hand to speak

authoritatively concerning the Egyptian cottons. This type is now being grown at Kunia, the Waipahu uplands and at the station trial grounds. In all these places the plants have thriven remarkably well. It has the general habit of the Sea Island type, but is a much ranker grower, the wood being very brittle in consequence, as is also characteristic of the Caravonicas. It matures intermediate between Sea Island and Caravonica, and thus far promises to out-yield all other types as an annual. Owing to its natural rank growth, it is believed that this variety is unsuited to wet localities in this warm climate.

The following varieties of cotton are now under test: *Sea Island type*—Seabrook, one strain of Georgia Sea Island; one strain of Florida Sea Island; five station selections of Sea Island. *Egyptian*—four strains of Mit Afifi, one strain of Ashmouni. *Upland*—Roger Big Boll, Triumph, Sunflower, Southern Hope, Parker, Chinese, Peterkin, Duke Long Staple; *Caravonica*—"Wool" [1], Caravonica "Silk," Caravonica Kidney.[2]

The above will be reported upon in detail at end of the harvest.

Two wild native Gossypiums (*G. tomentosum*), a low spreading shrub, 4 to 6 feet high, bearing yellow flowers and a short dark brown lint; and *G. drynarioides,* an arborescent type, bearing large, red Hibiscus-like flowers, and yielding a very dense dark brown lint, similar to the preceding), are being propagated with a view to using them as a basis for breeding work: it is believed some striking results may be obtained from crossing these varieties with commercial forms of cotton. The drought resistant qualities, and dark colored lints of these types is what especially commends them for the work in hand.

Time of Planting and Distances to Plant.

Season and location determine the time to plant. For warm, well drained soils, any time after January 1 and up to the first of March, is recommended regardless of variety, unless the season for harvest, whether for weather or labor conditions, must be considered. In cold, wet localities, planting had best be delayed till March or April.

[1] In their second year of growth.
[2] In their fourth year of growth.

Past experience would indicate that the smaller types of cotton, such as Sea Island and upland, should be planted 2 by 4 feet apart in dry locations, and 2½ by 5 feet apart in moist locations. For the Caravonica cottons, twice the above distances are recommended, and for Egyptian, an intermediate spacing. If to be grown as a perennial crop, every alternate plant in the row should be removed the second or third year. It is strongly urged that only one plant be left in a hill.

Improving a Strain.

As Hawaii must always depend upon the quality of her cotton product, rather than bulk, it becomes important that only the highest quality of fiber be maintained. To do this successfully, the planter must early acquaint himself with the qualities that constitute a superior type and work constantly for that ideal.

Should cotton be grown successfully as a perennial in Hawaii, it should be practicable in time, after having found the exceptional individual plant, to work over by budding an entire plantation to this type.

Two extensive cooperative experiments with cotton on a field scale, were begun in the early part of the year and will be reported upon in a later publication.

MISCELLANEOUS EXPERIMENTS.

The Chinese and Japanese matting sedges, (*Cyperus tegetformis* and *Juncus effusus*), which have been under test during the past two years, are holding their own, and a large stock of plants are available for distribution. Of the three plantings made by parties under the station's suggestion, the larger planting, covering about one and one-half acres, has not proved a success owing to the drying out of the pond to an extent never before known. Subsequently, the pond became flooded and the reeds took a new lease on life.

The two other plantings, each one-half acre in extent, are thriving and represent extreme conditions; the one, on submerged upland marsh, overflowed by fresh spring water; the other, a tide-water marsh too salt for any other culture.

During the year a comparative test was made of some fifty fodder and green-manuring plants, including alfalfa, cowpeas,

peanuts, soy beans, velvet beans and numerous other legumes; also corn, dry-land rices, wheat, oats and some perennial grasses. Numerous selections were made of the choicest individual plants, and a large amount of seed distributed.

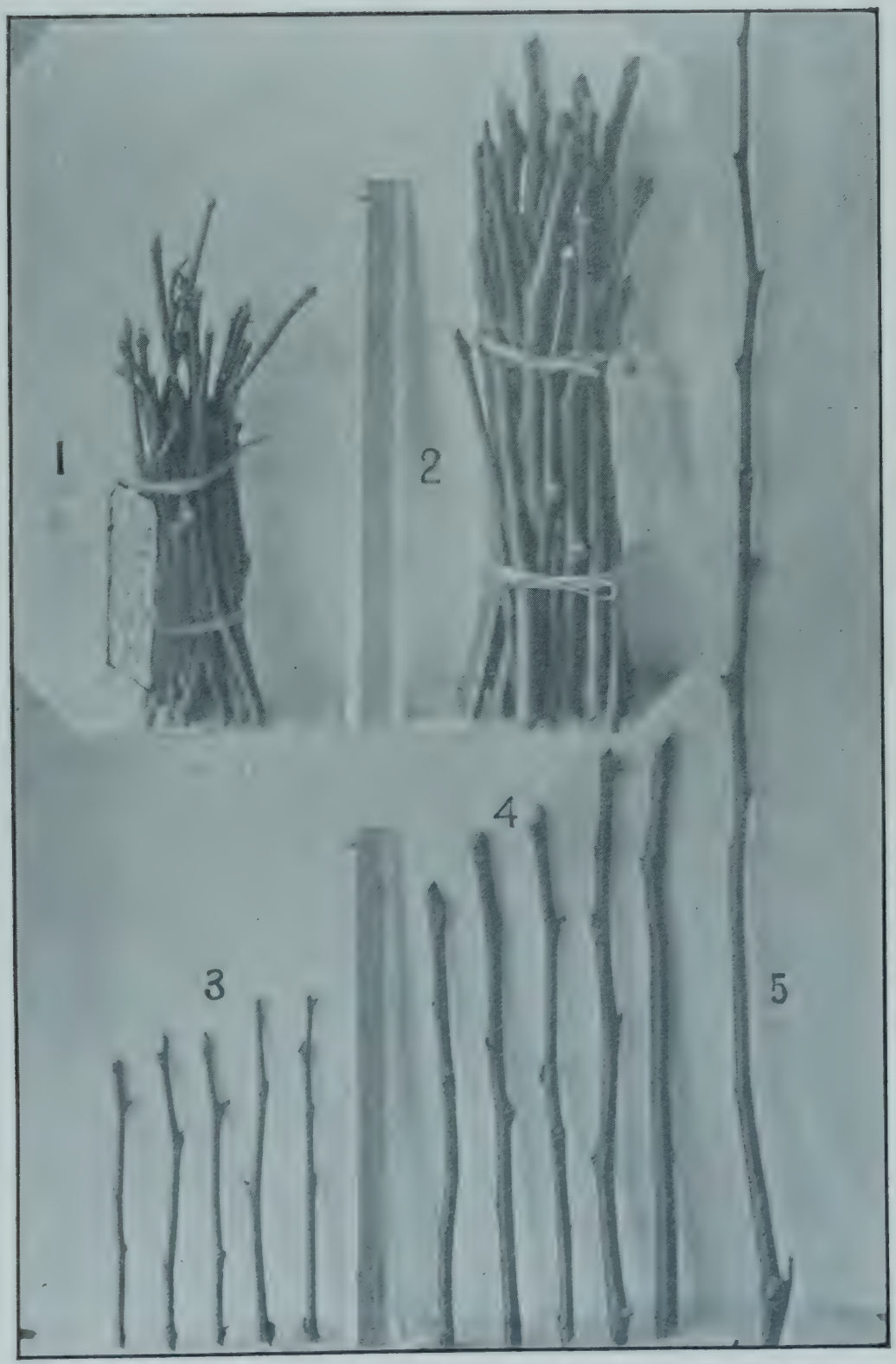
This department in common with other departments of the station, prepared both a federal and territorial exhibit for the Alaska-Yukon-Pacific Exposition. The specimens collected were all agronomic and consisted of 128 items for the federal and about an equal number but larger samples for the territorial exhibit.

Acknowledgement is due the station staff for much valuable assistance rendered this division.

THREE YEAR OLD PRUNED CARAVONICA COTTONS

1. Tall Pruned. 2. Low pruned. 3. Intermediate.

PLATE V



COTTON CUTTINGS

1, 3, Tip or soft wood cuttings. 2, 4, Butt or hard wood cuttings.

5, Dormant wood, suitable for making cuttings, or cion for budding or grafting.

PLATE VI FIG. 1.

FIG 2.

CARAVONICA COTTON GROWN FROM CUTTINGS.

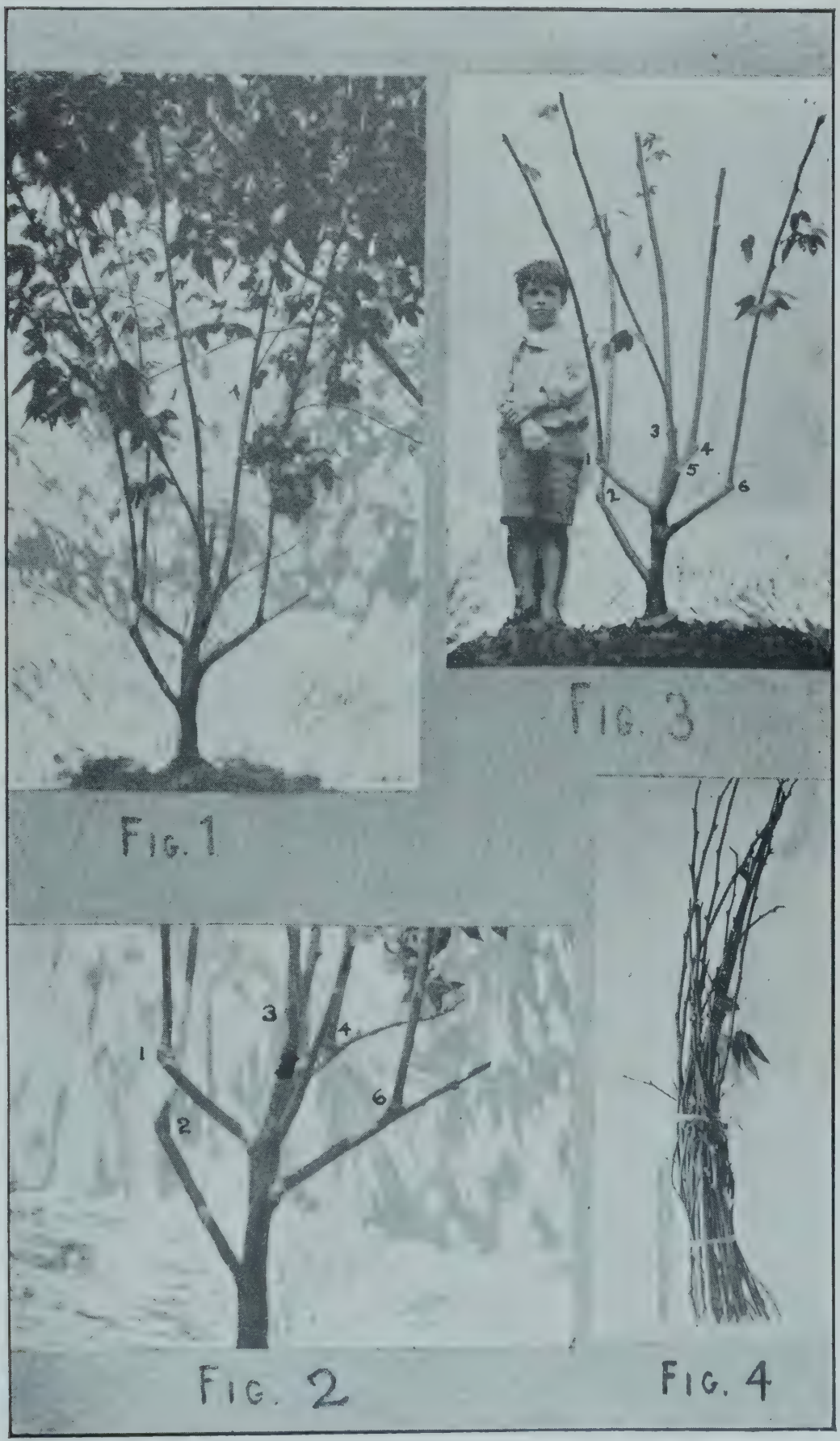


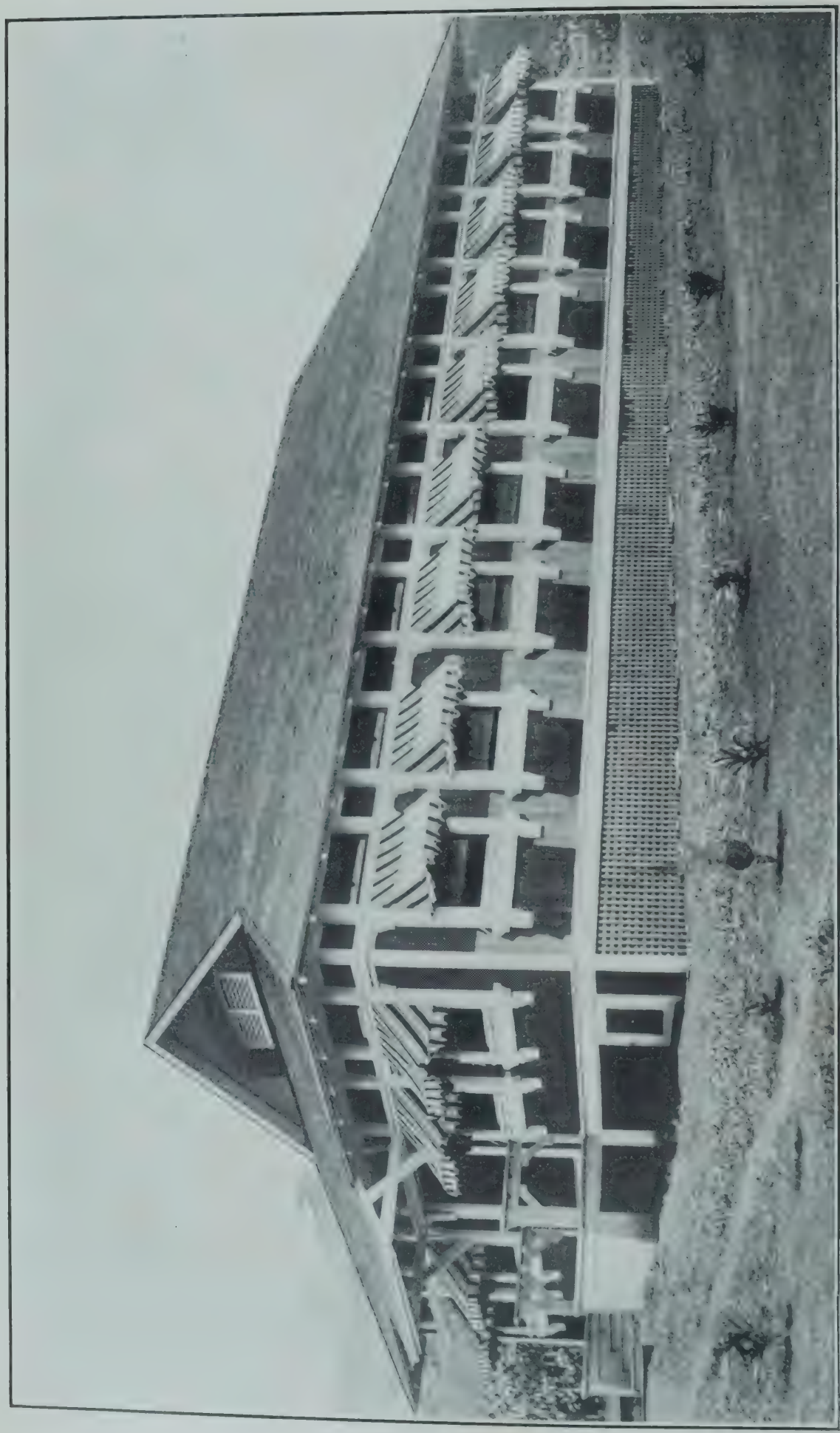
FIG. 1

FIG. 3

FIG. 2

FIG. 4

BUDDED COTTONS



1324 Issued May 6, 1911.

HAWAII AGRICULTURAL EXPERIMENT STATION,

E. V. WILCOX, Special Agent in Charge.

ANNUAL REPORT

OF THE

HAWAII AGRICULTURAL EXPERIMENT STATION

FOR

1910.

UNDER THE SUPERVISION OF

OFFICE OF EXPERIMENT STATIONS,

U. S. DEPARTMENT OF AGRICULTURE.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1911.

HAWAII AGRICULTURAL EXPERIMENT STATION, HONOLULU.

[Under the supervision of A. C. TRUE, Director of the Office of Experiment Stations, United States Department of Agriculture.]

WALTER H. EVANS, *Chief of Division of Insular Stations, Office of Experiment Stations.*

STATION STAFF.

E. V. WILCOX, *Special Agent in Charge.*
J. EDGAR HIGGINS, *Horticulturist.*
F. G. KRAUSS, *Agronomist.*
W. P. KELLEY, *Chemist.*
D. T. FULLAWAY, *Entomologist.*
ALICE R. THOMPSON, *Assistant Chemist.*
C. J. HUNN, *Assistant Horticulturist.*
V. S. HOLT, *Assistant in Horticulture.*

LETTER OF TRANSMITTAL.

HAWAII AGRICULTURAL EXPERIMENT STATION,
Honolulu, Hawaii, October 25, 1910.

SIR: I have the honor to transmit herewith and to recommend for publication the Annual Report of the Hawaii Agricultural Experiment Station for the fiscal year 1910.

Respectfully,

E. V. WILCOX,
Special Agent in Charge.

Dr. A. C. TRUE,
Director Office of Experiment Stations,
U. S. Department of Agriculture, Washington, D. C.

Publication recommended.

A. C. TRUE, *Director.*

Publication authorized.

JAMES WILSON, *Secretary of Agriculture.*

CONTENTS.

	Page.
Summary of investigations	9
Buildings	9
Grounds	9
Demonstration farms	9
Cooperative experiments	10
Rational soil program	11
Rice	12
Cotton	13
Pineapples	14
Horticultural investigations	16
Entomological investigations	17
Rubber	17
Taro	18
Broom corn	18
Report of the entomologist	19
General insect notes	19
Algaroba weevil parasites	20
Insects of field crops	21
Report of the horticulturist	25
Avocado	25
Propagation	25
Insect control	26
Disease control	27
Varieties	27
Fertilizer trials	29
Miscellaneous studies	30
Mango	30
Propagation	30
Transplanting	30
Root system	31
Insect control	31
Disease control	32
Varieties	32
Papayas	33
Monœcious and diœcious types	33
Breeding problems	34
Citrus fruits	35
Insect control	35
New varieties	36
Sweet potatoes	36
Miscellaneous notes	37
Garcinia mangostana	37
Carissa arduina	38
Litchi	38
Deciduous fruits	39

Report of the horticulturist—Continued.
Miscellaneous notes—Continued. Page.
Tree tanglefoot 39
Pigeon pea 40
Rattan palms 40
Bougainvillæa disease 40
Report of the chemist 41
Pineapple soil investigations 41
Rice investigations 43
Fertilizer experiments with cotton and rubber 44
The composition of pineapples 45
Report of the agronomist 51
Rice investigations 51
Imports and exports 51
Rice in Japan 52
Selection and breeding 54
Rotation 55
Cotton experiments 57
Kunia cooperative cotton experiment 57
Waipahu cooperative cotton experiment 60
Yields 61
Cotton breeding 62
Miscellaneous crops 63
Taro 64

ILLUSTRATIONS.

PLATES.

Page.

New office and library building ..... Frontispiece.

PLATE I. A 5-year-old avocado tree, top worked to a selected variety by budding 24

II. Fig. 1.—*Carissa arduina*, a valuable fruit and hedge plant. Fig. 2.—Pigeon peas as a windbreak for nursery stock 38

III. Types of rice considered of highest culinary quality in Japan 54

IV. Japanese rices not acceptable to Japanese consumer 54

V. Cooperative cotton experiments. Fig. 1.—Caravonica "wool" cotton six months from seeding. Fig. 2.—Caravonica "wool" cotton nine months from seeding 58

VI. Cooperative cotton experiments. Fig. 1.—Pruning 1-year-old Caravonica "wool" cotton. Fig. 2.—Second season's growth of Caravonica "wool" cotton 58

VII. Fig. 1.—Three-year-old-Caravonica cotton tree budded to superior strain, three months' growth after budding. Fig. 2.—Ideal types of Caravonica "wool" cotton bolls 62

VIII. Fig. 1.—One-year-old cuttings of Caravonica cotton. Fig. 2.—Plants grown from cuttings, six months after transplanting 62

TEXT FIGURES.

FIG. 1. Form of fruit and seed of avocado No. 149 28

2. Form of fruit and seed of Moanalua avocado 28

3. Form of fruit and seed of avocado No. 150 29

4. Form of fruit and seed of avocado No. 145 29

ANNUAL REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION FOR 1910.

SUMMARY OF INVESTIGATIONS.

By E. V. Wilcox, *Special Agent in Charge.*

BUILDINGS.

During the fiscal year ended June 30, 1910, a new office building (frontispiece) was erected from funds generously supplied by the Territory of Hawaii. The new building is better lighted than the old one; gives room for a more convenient library, and also offices for the special agent in charge, clerical force, entomologist, and agronomist, as well as for a mailing room. The chemical laboratory in the old cement building was inconvenient and has, therefore, been rearranged and new tables have been constructed for analytical and general work. A more efficient hood has also been devised for carrying off the fumes, and a new room arranged for nitrogen determinations.

GROUNDS.

Some of the land nearest Honolulu belonging to the experiment station has been heretofore in an uncultivated and unimproved condition. During the year this land was cleared and planted in Bermuda grass for lawn purposes or in various crops used in experiments. In addition, about 10 acres of land, lying on the slope of the station grounds, at an elevation of about 250 feet, has been thoroughly cleared of shrubby undergrowth and about one-half of it has been planted to cotton and other crops. The chief buildings belonging to the station are erected on grounds which heretofore belonged to the Navy Department and which were temporarily turned over to the use of the Agricultural Department. During the fiscal year this land was definitely transferred to the Department of Agriculture by an agreement reached between the Secretary of the Navy and the Secretary of Agriculture.

DEMONSTRATION FARMS.

It has been felt for some time that on account of the fact that the Territory consists of several islands, located at considerable distances apart, demonstration farms were desirable in order to bring the work of the station more prominently before the inhabitants of the other islands of the group as well as on Oahu. The problem of establish-

ing demonstration farms in Hawaii is somewhat different from that which must be met in the States of the mainland. Farming communities are composed of different races, and a large proportion of the farmers who have small holdings are quite unacquainted with the purposes of demonstration farms. It appears, therefore, inadvisable to carry on such work according to the methods long in vogue on the mainland.

The objections to those methods, in so far as Hawaii is concerned, are chiefly two. Perhaps the more important is the matter of funds, which are at present inadequate to carry on demonstration farms on each of the islands independently of private help. The Territory has freely offered to turn over the necessary land to the station for such experiments, but the Territorial funds available for station use are not adequate for the maintenance of independent demonstration farms. There would be required a large outlay for fencing, buildings, machinery, horses or mules, foremen, and laborers. Such an arrangement would also result in the production of a considerable amount of material which would have to be sold in the open market. An objection has been made to this on the grounds that the station would, in a sense, be competing with practical farmers and with an unfair financial advantage.

The second objection to the mainland program of demonstration farms follows from the nature of the farming population in Hawaii. A community of Portuguese and native farmers can best be persuaded to adopt improved methods, actually shown to be advantageous, when these methods are put in operation upon farms belonging to one of the most progressive farmers in each community. It therefore seems best to establish demonstration farms essentially on the basis of a cooperative experiment. Several such farms will be put in operation during the fall of 1910. The program consists essentially in making an arrangement with one of the best farmers in each community to adopt certain modifications of cultural methods which the station will suggest and to keep careful record of the results of such work for the use of the station and all his fellow farmers. By this method it is believed that the results shown on the demonstration farms will be more readily accepted and will more obviously meet the exact conditions under which the farmer must labor.

COOPERATIVE EXPERIMENTS.

During the time which has been occupied in determining upon a practical method of carrying on demonstration farms, practically the plan outlined above has been put in operation on a number of large estates. The station has undertaken the supervision of certain cultural, soil, and fertilizer experiments on Molokai, Maui, Hawaii, and Oahu. The crops involved in these experiments are pineapples,

cotton, rubber, corn, legumes, rice, sorghum, and a number of miscellaneous forage crops. These cooperative experiments have in all cases moved along very smoothly, for the reason that the private individuals concerned were intensely interested in bettering their cultural methods and establishing more extensive areas of cultivated crops, and also, for the reason that a highly intelligent and reliable control was exercised over the management of the experiments and the keeping of records. While cooperative experiments on the mainland and elsewhere, in many instances, cause considerable annoyance to both the station and the private individuals concerned, the cooperative experiments in Hawaii have been strikingly free from such troubles. So long, therefore, as the work can be carried on with relatively little interference with the time and energy of the station staff, it seems highly desirable to continue them where satisfactory arrangements can be made. It is a pleasant duty to acknowledge the active and intelligent interest which has everywhere been shown in the cooperative experiments thus far carried on by the station.

RATIONAL SOIL PROGRAM.

The soils of the Hawaiian Islands are very different in several respects from those which are familiar to farmers and agricultural workers on the mainland. In the first place, the Hawaiian soils contain high percentages of iron in various forms (say from 15 to 30 per cent). In addition to the high iron content, the soils contain more titanium than mainland soils, and in some localities, also a large amount (up to 9 per cent) of manganese. The presence of the large quantity of iron in Hawaiian soils gives them physical properties which are seldom met with in soils on the mainland. Wherever special attention is not given to cultivation, the soils rapidly become impervious to water and air and the iron present in the soil is reduced to the ferrous state. This, as is well known, is injurious to plant growth and is instrumental in preventing adequate aeration of the soil. Moreover, when the iron exists in the ferrous state and the soil can not be aerated, the use of fertilizers gives little or no benefit. It is therefore necessary to adopt a rational soil program, with the central idea that of securing a better aeration and better physical properties of the soil. Studies, which are designed to throw light on the practical methods of accomplishing such a result, are now in progress at the station, and the suggestions, already made by the station chemist, are being put into practice in a number of localities. It may be truthfully said that in many localities the chief soil problems are concerned with the physical rather than the chemical properties of the soil. Improper aeration not only causes the iron to become reduced to the ferrous state, but may also prevent the utilization by the plant of the plant food naturally present in the soils.

The study of cultural and rotation methods for securing a better aeration of the soil will be continued during the coming year, both in pot and field cultures.

RICE.

The chemical work on rice during the fiscal year was concerned chiefly with the study of the time or stage of growth at which fertilizers should be applied and the influence of various elements of plant food upon the composition of the rice plant. It was found during these experiments that the program adopted by the growers, in using fertilizers on rice, was somewhat ill advised, as judged by the physiology of the rice plant. It appears that the rice plant, by the time it is two-thirds grown, has already taken up about four-fifths of the nitrogen and phosphoric acid, and nine-tenths of the potash which will be absorbed during its whole growth; and that, therefore, fertilizers should preferably be applied before planting the rice, or, at any rate, during the very early stages. The value of nitrogen in rice culture has proved in the station experiments to be greater than was previously suspected. On some of the rice soils the use of phosphoric acid and potash gives no beneficial results. On these soils nitrogen alone produces as heavy yields as do complete fertilizers.

It was soon noted in experimenting with fertilizers on rice that nitrate of soda appeared to produce no beneficial effect, while ammonium sulphate was very active in promoting growth and yield of grain. This point has been carefully studied through two crops of rice at the trial grounds, and through several series of pot experiments. In almost every instance nitrate of soda gives no increase of growth over that observed in check plats or check pots; in fact, while it may be too early to conclude positively, the pot experiments thus far carried out indicate that the rice plant can not use nitrogen in the form of nitrate, but only in the form of ammonia. It had already been suspected by other investigators that ammonia was better than nitrate for rice, but it has hitherto never been shown that the rice can not use nitrogen in the form of nitrate.

The importation of rice from Japan continues to increase, and the production of rice in Hawaii has slightly decreased. In order to get further information on the cause of this condition, and to learn more in detail the methods of rice cultivation in Japan and the varieties used in that country, the agronomist visited Japan and China during the past year. It was found that the Japanese have a decided preference for certain varieties of rice which are almost the only kinds exported to Hawaii for use by the Japanese population, and that these varieties are claimed to have certain superior culinary qualities which can not be definitely described. Seed of about 150 varieties of rice was brought back from Japan, including a considerable quantity of seed of four of the best varieties grown in that

country. These have been distributed to growers and reports regarding their behavior are expected during the coming year. A test of fertilizers on a commercial scale will be carried out for the purpose of demonstrating the results which have already been obtained at the trial grounds and in pot cultures. It is believed that these demonstrations will lead to a change of method in the application of fertilizers, resulting in greater economy and increased growth.

Experiments are also under way with a number of legumes and other crops, some of which were recently imported from Japan, to be used in rotation with rice in order to maintain the high yield which has hitherto prevailed in Hawaii.

COTTON.

Experiments with cotton were begun by the station three years ago and have yielded striking results in certain localities in which commercial plantings, to the extent of about 500 acres, have been made. During the coming year these plantings will be greatly increased. A number of points have been quite clearly demonstrated during these experiments. It has been shown that cotton will thrive under a wide range of rainfall—from 25 to 100 inches per year—and at a considerable variation of altitude, from sea level to 1,600 feet. The most favorable locations, however, are low-lying lands near the seashore and protected by algaroba, or other windbreaks, from the winds which occur during the winter. Although at elevations below 300 feet a temperature as low as 50° F. is very rare in Hawaii, nevertheless, at such a temperature cotton shows the effect in a marked degree. The leaves even may turn brown, as if they had been frosted. With regard to rainfall, a moderate amount per year is decidedly more favorable for the growth of cotton than a higher or lower rate of precipitation.

One difficulty which has been experienced in growing Sea Island cotton in Hawaii is that of excessive yield, which results in a too prostrate form of growth. In one locality on the windward side of Oahu, where the rainfall is about 70 inches per year, 2 acres of Sea Island cotton required about 5,000 props in order to keep the branches from lying upon the ground and causing the bolls to rot. In this respect the Caravonica cotton is superior to Sea Island, since it invariably has an upright habit of growth. The difficulty experienced with the prostrate habit of the Sea Island can be appreciated from a consideration of the fact that in the 2-acre field just mentioned and in another 1-acre field, on the leeward side of Oahu, the average number of bolls per plant was 700, and on one tree 1,200 bolls were counted at one time. This produces a weight under which the slender branches of the Sea Island can not support themselves in an upright position. An elaborate series of pruning experiments is now under

way with the idea of learning a method by which an upright growth can be induced in the Sea Island cotton, at least for the second and subsequent years of the crop. Some promise is already held out by these experiments. A strain of Sea Island, secured from one of the best plantations on James Island, S. C., shows a more upright habit of growth than any other strain of Sea Island which has thus far been secured.

The Caravonica cotton continues to give promising results. During the first year of its growth the yield appears to be normally low, but in the second year a heavy yield is obtained, which, in conjunction with the greater ease of picking and the higher percentage of lint, makes a choice between Sea Island and Caravonica somewhat doubtful. Egyptian cotton has given results as satisfactory as those obtained with Sea Island. The strains of Egyptian cotton with which the station is experimenting grow rather more vigorously than the Sea Island, and the yield is perhaps slightly larger. The place which Egyptian cotton should take in the agriculture of Hawaii will largely be determined by the future demands of the market for the three chief types of cotton now grown in the Territory. In addition to Sea Island, Caravonica, and Egyptian cottons, experiments are being made with Chinese upland, a number of varieties of upland from the Southern States, and a cotton with red lint, from Cuba. It is proposed to make a reciprocal cross between Sea Island and Kidney cottons in order to determine whether Caravonica cotton was originated in this manner and whether an improvement upon the ordinary type of Caravonica can thus be secured. Several plants have been found in different localities in the Territory where a natural cross between a pure Sea Island and a pure Kidney cotton could have taken place, and these plants strikingly resemble, in habit of growth and quality of lint, the ordinary type of Caravonica cotton.

It has been found that pure strains can be propagated by means of cotton cuttings, and a number of cuttings will come into bearing during the present season. In addition to this method of propagation budding has been tried on a large scale. Propagation is an easy matter by the method of budding, but the economy of the method on a commercial scale has not yet been determined. According to the present outlook it seems an economic proposition to bud over large areas with bud wood from the best plants, and thus secure a uniform cotton over the whole field. This method would, of course, have no value except where cotton is cultivated as a perennial crop.

PINEAPPLES.

In connection with the study of manganese in the soil as affecting the growth of pineapples, experiments have been made with a number of crops which could possibly be grown in rotation with pineapples or

to replace pineapples in the manganiferous soils. For this purpose corn, rice, and various other cereals, tobacco, cotton, legumes, garden vegetables, and fruit trees were used. It has been found that manganese invariably causes a yellowing of all the leaves and a premature falling of the lower leaves on all plants with which experiments have been made. The plants may subsequently become green, just before the fruiting period, at which time a vigorous growth may be observed for a short period. The ultimate outcome, however, is in all instances a decidedly stunted growth and small yield. The root system in manganiferous soils is peculiar in the length and fineness of the small roots. The ultimate outcome in pot experiments is a root system strikingly different from that in ordinary garden soils. Apparently the extreme fineness of the roots is due to the lack of resistance which they meet in penetrating manganiferous soils. These soils invariably remain loose like ashes, no matter how frequently or heavily they may be irrigated.

In the fertilizer experiments with pineapples, which are being continued by the chemist, it has been found that phosphates, particularly acid and reverted phosphates, have a beneficial effect upon the growth of the pineapple plants, probably for the reason that these materials tend to render the manganiferous salts in the soil less soluble. Lime, on the other hand, is decidedly injurious on manganiferous soils, as shown by the experiments of the station and by tests which have been tried by growers on a commercial scale. The injurious effect of lime is possibly due to the fact that it helps to furnish conditions favorable for the formation of the higher oxids of manganese, which are the most injurious salts of this mineral.

A study of the ripening of pineapples has disclosed the fact that the sugar content of the fruit is derived exclusively from the leaves of the plant and does not increase after the fruit has been removed from the plant. If pineapples are picked green and allowed to ripen the sugar content at complete ripeness is the same as it was when the fruit was removed from the plants. An analysis of the fruit shows that they contain no substance which can be changed into sugar during the ripening process. Fruits picked too green and allowed to ripen, therefore, lack greatly in sugar content and in flavor. The sugar content of green fruits, or fruits ripened after being picked too green, is about 2 or 3 per cent, while that of fruits ripened on the plant ranges from 9 to 15 per cent. The ripening process in fruits picked green appears to consist largely in a softening of the tissues. A microscopic examination of sections of green pineapples shows that the cell walls in the parenchyma of the fruit are greatly thickened, but become extremely thin in ripening. It is obvious from these facts that in order to obtain a good flavor in fresh fruit the fruit should not be picked until the sugar content has

become fairly high and the fruits have turned yellow to the extent of about one-fourth their length at the base.

HORTICULTURAL INVESTIGATIONS.

Satisfactory progress has been made in propagating avocados, especially by budding. The method reported in the last annual report has been put into operation on other trees, and the results thus far obtained are very promising. A number of difficulties, particularly the drying of the bud, have been successfully overcome.

Attention has been given to the varieties of avocados to be found in the Territory. There appear to be quite a number of recognizable varieties, but most of them have not been definitely named. Four varieties of special merit have received attention on account of their being especially adapted to shipping, extra late, extra early, or of exceptional quality.

Similarly with mangoes, the methods of propagation reported in the last report and in Bulletin 20 of this station, have continued to give good results. In one case fruit was borne upon a graft within eighteen months after insertion. Continued tests of the possibility of transplanting mango trees have shown that this operation is relatively simple and successful in the majority of cases. The insect pests and fungus diseases of avocados and mangoes have not proved to be especially serious when proper treatments are applied.

A large collection of papaya seed was made from trees in various localities whose fruit was reported to be of special value or of excellent flavor. From the observations made on papayas there seem to be two distinct types (diœcious and monœcious), in Hawaii, with various intermediate forms. The diœcious type occasionally has a fruit borne among the staminate flowers. The monœcious type of papaya bears fruit on every tree. The monœcious type has both perfect and staminate flowers on the same tree and is the one which lends itself best to breeding and selection. As long as the diœcious type is used one must depend upon cross-fertilization, and the characters can not be fixed as readily as where close fertilization can be carried on. Moreover, when the diœcious type is used, a certain percentage of trees will prove to be males, and therefore sterile. A large amount of space in the orchards is thus lost, as well as the time which has been expended in cultivating the male trees. There is considerable evidence that ultimately a strain of papayas will be produced which will come true to seed. Since seed is the only apparent practical means of propagating papayas, it seems wise to make every possible effort to obtain seed with fixed characters.

It was considered desirable to learn the state of the market in San Francisco for sweet potatoes during the season when sweet potatoes are not to be had in that city from local sources. For this purpose

two shipments were made from the station, with the result that all varieties, of whatever color, if of standard size, were accepted at 8 cents per pound in San Francisco. The market price of sweet potatoes in Honolulu is usually from 70 cents to $1 per hundred. It would be, therefore, obviously a good practice to make at least one planting of sweet potatoes for the purpose of shipment to California sometime during the interval between the first of May and the middle of July.

ENTOMOLOGICAL INVESTIGATIONS.

During the year the attention of the entomologist was directed to a number of miscellaneous insect outbreaks, to the insects of the sweet potato, and certain enemies of forage crops, and to the propagation of parasites, particularly for the algaroba bean weevil. A bulletin on sweet potato insects has been prepared and will be issued during the coming year. Considerable time has been spent in studying the insect enemies of corn, and it is proposed to take up a study of the chief pests of the principal forage crops in Hawaii as occasion may offer.

More than 2,000 parasites of bean weevils, obtained through the Bureau of Entomology of the United States Department of Agriculture, in mesquite pods, were reared at the station and turned out at various points on Oahu, Maui, and Molokai. The result of this importation of parasites is not yet apparent, but one egg parasite appears to have become quite effective during the past season.

RUBBER.

Opportunity was had during the year to visit all of the commercial rubber plantings of the Territory. These are located on the windward side of Maui and in the Puna district of Hawaii. A satisfactory growth is manifested everywhere in the rubber plantations between the lowest altitudes and an elevation of 1,400 feet. No commercial plantings have been made at higher elevations. On all of the plantations Ceara rubber grows much more rapidly than Hevea rubber. The latter does not make as rapid growth in Hawaii as it is reported to make in the Straits Settlements and Ceylon. The question whether Hevea should be extensively planted in Hawaii seems to depend on whether the ultimate yield will be enough larger than that of Ceara to counterbalance the long waiting period for the first tapping.

Wherever clean cultivation has been adopted, the growth of the trees is incomparably more rapid than where no cultivation has been practiced. Trees which have received clean cultivation since planting are larger at 2 years of age than 6-year-old trees which have not been cultivated. The necessity of cultivation is apparently, for the

most part, due to the lack of aeration and the presence of stagnant water in the soil. As soon as cultivation is begun the soils allow the passage of water much more freely and drainage is decidedly better.

Where the rocky nature of the soil will not permit cultivation, it is necessary to destroy the weeds by other means, and a comparative experiment has been made to determine the effectiveness of sulphate of iron and arsenite of soda as herbicides. The cost of spraying with arsenite of soda is a little less than with sulphate of iron, and its effectiveness appears to be greater. About 500 acres of land in the rubber plantations have been sprayed with arsenite of soda. This land is of a rough nature and is covered with both shrubby and herbaceous weeds of a great variety. From one to three applications of arsenite of soda are required to clean the land of all vegetation. Even lantana and other shrubby plants are killed down to the ground by the spray. The total cost for material and labor ranges from $1.25 to $2 per acre; the expense, is, therefore, much less than that incurred by hand or horse implements. Arsenite of soda has also been used at the station on a number of weeds, including Japanese nut grass, which is probably the worst weed in cultivated land in the Territory of Hawaii. This weed is killed down to the ground by a single application of either arsenite of soda or sulphate of iron. It sprouts up again after a considerable interval, but the young plants are weak and may be destroyed by a second application.

TARO.

There are lands in the Territory which are known to have been cultivated almost continuously to taro for several hundred years. The station has made an arrangement to carry on a fertilizer test on a taro plantation which has been continuously in this crop for 200 years. In some fields of the plantation a decided diminution in yield has been noticed. On account of the active interest which the plantation managers take in the matter, this is believed to be a particularly favorable opportunity to learn the fertilizer requirements of taro and to compare them with conditions met in rice culture under water.

BROOM CORN.

A considerable quantity of broom-corn seed was distributed to growers in different parts of the Territory, and about 1 acre was planted on the station grounds. The seed was planted rather late, and the crop was, therefore, attacked by plant lice to a most unusual extent. The growth of uninfested plants was quite satisfactory, and heads of normal size are now forming. If the cultivation of broom corn proves to be a paying line of farming, it is proposed to build a broom factory in Honolulu for the local trade.

REPORT OF THE ENTOMOLOGIST.

By D. T. Fullaway.

GENERAL NOTES.

During the year the usual insects were noticed attacking agricultural crops. Some recently introduced pests have increased to an alarming extent and exemplify the destructiveness of harmful insects in the absence of natural enemies. Outbreaks of cutworms and army worms occurred in many localities during the winter, causing severe losses. The rice crop was not affected this year, but several wheat fields were devastated. The corn leaf aphis contributed to the destruction of the wheat and barley crops. In the fall pineapple plants on the Consolidated Pineapple Co.'s plantation were badly damaged by an introduced locustid, *Xiphidium varipenne*. The insect attacked the leaves of the pineapple, making large abrasions which permitted the entrance of fungus hyphæ, causing the leaves to wilt and die back. This feeding habit is very extraordinary for the insect, which usually feeds on pollen. The eggs of the locustid are much parasitized, so that it is not likely to become a serious pest of pineapples. The injury, in fact, has not continued. The edible nuts of the litchi tree in several Honolulu gardens were badly attacked in July by a tortricid moth, *Cryptophlebia illepida*. The larvæ bore into the succulent fruit and render it unfit for use. On the trees of one private orchard practically the entire crop was destroyed. An attempt was made the present year to prevent this loss by spraying, but the crop of nuts was small, and the moth did not appear to be very troublesome, although it was present as usual in klu and koa pods.

Some attention was given to bee keeping, but nothing done in the way of investigation. It is a pleasure to record that this minor industry is now well established here. The bee keepers are progressive, and the industry is growing. One corporation keeping bees has gone extensively into queen rearing, and during the last year several Japanese and Australian apiaries were supplied with queens from these islands. No new bee plants were introduced, but the better of those already secured were rather freely distributed.

Numerous inquiries which were received during the year in regard to insect pests and remedies for them were answered by correspondence. In some cases personal inspection of the conditions was made

and advice offered. The station's collection of economic insects was maintained and much material added. New office rooms and much new and better equipment were secured.

While matters of immediate concern received due attention, the work of the entomologist was, as far as possible, confined to definite lines of investigation. This kind of work is believed to be more progressive and permanent than scattered efforts with an immediate object in view.

ALGAROBA WEEVIL PARASITES.

At the beginning of the year shipments of bean weevil parasites were received through the cooperation of the Bureau of Entomology, United States Department of Agriculture, and much time was given to taking care of the material, securing the parasites, and releasing them. Later a search was made to find if they had become established, but this could not be verified except in the case of the minute egg parasite (Trichogramminæ), which bred freely from the eggs of bean weevils on beans brought in from the field. The following is a detailed report of this attempted introduction:

Lot 1 (June). One box of pods of the mesquite, infested with *Bruchus prosopis* and *B. amicus*, from Dr. F. H. Chittenden. Parasites obtained from this lot were all *Heterospilus* sp.

Lot 2 (July). Three boxes of mesquite beans containing *B. prosopis* and *B. amicus*, from Mr. W. D. Hunter. Parasites obtained were *Heterospilus* sp. and *Urosigalphus bruchiphagus*.

Lot 3 (August). One large box containing 30 pounds of mesquite beans with *B. prosopis* and *B. amicus*, from Mr. W. D. Hunter. Parasites obtained were *Heterospilus* sp., *Urosigalphus bruchiphagus*, *Eurytoma tylodermatis*, and Trichogrammid.

Lot 4 (August). Two boxes containing *B. prosopis* and *B. amicus*, from Mr. W. D. Hunter. Parasites obtained principally *Heterospilus* sp.

Lot 5 (September). Two boxes containing *B. prosopis* and *B. amicus*, from Mr. W. D. Hunter. Parasites obtained were *Heterospilus* sp. and *Urosigalphus bruchiphagus*.

Lot 6 (September). One large box containing 30 pounds of mesquite beans with *B. prosopis* and *B. amicus*. Parasites obtained were *Heterospilus* sp., *Urosigalphus bruchiphagus*, *Eurytoma tylodermatis*, *Cerambycobius cushmani*, and Trichogrammid.

All attempts to breed the parasites in confinement failed. The parasite house, which offered the only secure place for breeding work, was too dry and hot. In the breeding house it was necessary to place the material in breeding jars and there the beans molded. Under the circumstances it was necessary to liberate the parasites at once and allow them to take their chances in the field. On advice, only

Heterospilus sp. was released, and in all 2,303 were liberated—a fair proportion being males, with which the females had been confined from five to ten days before liberation. This parasite has not been seen since. The parasites were mostly liberated on the grounds of the experiment station. One lot of 250 specimens was released on the Alexander and Baldwin plantation at Puunene, Maui; another lot of 200 on the Isenberg ranch at Waialae, Oahu; and another lot of 100 on the Molokai ranch near Kaunakakai. Attempts to breed *Eurytoma tylodermatis*, of which probably 50 were obtained, in confinement were unsuccessful.

INSECTS OF FIELD CROPS.

Considerable time was given during the winter to the investigation of the insects affecting field crops. The greatest hindrance to the diversification of agriculture in these islands has been the ravages of insects, and numerous attempts to grow cereals and the ordinary field crops have ended in failure, owing to sudden and severe attacks of insect pests which have been half-heartedly and unsuccessfully coped with. The object of the investigation was to learn what insects attack field crops and their method of attack, in order to suggest means of combating them successfuly. An excellent opportunity was offered to begin this kind of a study in the 200-acre experiment at Kunia, on this island. The locality in which the Kunia Development Co.'s operations are being conducted is typical of much of the land that is available for diversified farming. It was new land, without water, and close to the mountains. All the elements of chance in diversified farming were present. The results of the first year's cultivation suggested plainly that success or nonsuccess depends largely on whether or not effective measures are adopted to suppress insect pests and are applied with thoroughness.

The crops under observation were corn, wheat, barley, oats, jack beans, and cotton.

CORN.

The following insects were observed to attack corn:

Cutworms (*Agrotis ypsilon* and *A. crinigera*).[1]
Army worm (*Cirphis unipuncta*).[1]
Grass army worm (*Spodoptera mauritia*).[1]
Looper (*Plusia chalcites*).
Angoumois grain moth (*Sitotroga cerealella*).[2]
Corn leaf aphis (*Aphis maidis*).[3]
Corn leafhopper (*Peregrinus maidis*).
Rice weevil (*Calandra oryza*).

[1] Hawaiian Sugar Planters' Sta., Div. Ent. Bul. 7, 1909.
[2] Hawaiian Planters' Record, 2 (1910), No. 2, p. 102.
[3] Hawaii Sta. Rpt. 1909.

Wireworm (*Simodactylus cinnamomeus*).
Tenebrionid beetle (*Epitragus diremptus*).
Cryptoblabes aliena.[1]
Batrachedra rileyi.[1]
Amorbia emigratella.[2]
Opatrum serratum.
Adoretus tenuimaculatus.
Araecerus fasciculatus.
Plodia interpunctella.
Ephestia elutella.
Setamorpha sp. (Reared by Swezey.)
Catorama mexicana. (Reared by Swezey.)
Nitidulid. (Reared by Swezey.)

WHEAT.

The following insects were observed attacking wheat:
Cutworm (*Agrotis crinigera*).[3]
Army worm (*Cirphis unipuncta*).[3]
Grass army worm (*Spodoptera mauritia*).[3]
Looper (*Plusia chalcites*).
Leaf roller (*Omiodes localis*).[4]
Corn leaf aphis (*Aphis maidis*).[5]
Opatrum serratum.
Epitragus diremptus.
Wireworm (*Simodactylus cinnamomeus*).

BARLEY.

The following insect was observed on barley:
Corn leaf aphis (*Aphis maidis*).[5]

JACK BEAN.

The following insects were observed on the jack bean:
Grass army worm (*Spodoptera mauritia*).[3]
Leaf miner (*Agromyza* sp.).

COTTON.[6]

The following insects were observed attacking cotton:
Cutworm (*Agrotis crinigera*).[3]
Grass army worm (*Spodoptera mauritia*).[3]
Cotton aphis (*Aphis gossypii*).[5]

---

[1] Hawaiian Sugar Planters' Sta., Div. Ent. Bul. 6, 1909.
[2] Hawaii Sta. Bul. 22, 1910.
[3] Hawaiian Sugar Planters' Sta., Div. Ent. Bul. 7, 1909.
[4] Hawaiian Sugar Planters' Sta., Div. Ent. Bul. 5, 1907.
[5] Hawaii Sta. Rpt. 1909.
[6] Hawaii Sta. Bul. 18, 1909.

Many of these pests are discussed in technical papers, in which life histories, remedies, natural enemies, etc., are given. References to these papers are made opposite the name of the insect. The following notes of observations at Kunia in connection with these crops are offered:

Cutworms and army worms undoubtedly did the most damage to the corn. Plants several weeks old in sections of the fields were so badly eaten that replanting became necessary. In other sections plants were literally stripped, both stalk and ear. The lower leaves were badly frayed and skeletonized by *Plusia chalcites* and the young larvæ of *Spodoptera mauritia*, but this injury is negligible. The corn leafhopper and corn leaf aphis are at times very injurious, especially to young plants. The ripening ears were attacked by *Cryptoblabes aliena*, *Amorbia emigratella*, and *Batrachedra rileyi*, which work in the silk at the flower end, also eating some of the cob. These insects attacking the standing corn are to be expected and can and ought to be systematically fought. For cutworms and army worms, the use of light traps in addition to poison bait is suggested. It might also be profitable to spray or dust the plants once or twice with arsenate of lead. The aphis and leafhopper may be sprayed with tobacco decoction, but they are difficult to control artificially.

The insects which attack matured ears or stored corn, such as the Angoumois grain moth, corn seed weevil, etc., can be best controlled by fumigating the stored corn. Corn stored in a tight bin may be fumigated with carbon bisulphid, 1 pound to 1,000 cubic feet; if the storeroom is not tight, the dose should be doubled.

Cutworms, army worms, and corn leaf aphis did the greatest damage to the wheat and barley, and in order to grow these grains it seems essential to control these pests in some way. The remedies suggested above are the only practical ones that can now be recommended, but the present situation might be greatly altered by the introduction of good parasites for this class of pests.

The dipterous leaf miner infesting jack beans gave this crop a very ragged appearance, and in sections the plants were eaten down to the ground by the army worm. The leaf miner is parasitized and is troublesome only at times. The army worm can be controlled with the remedies mentioned above.

The cotton aphis and climbing cutworms did the most damage to the cotton during the winter. The aphis was particularly bad, becoming so abundant as to cover both stems and foliage, and killing some plants. It is difficult to control by artificial means, but a spray of kerosene emulsion or tobacco decoction might be beneficial. Climbing cutworms should be fought with poisoned bait or by spraying with arsenate of lead.

In the spring the insects attacking the sweet potato were studied. The sweet potato is extensively cultivated here and is a staple article of food, especially among the Hawaiians and poorer classes. It has a number of insect enemies which damage the crop more or less, but do not prevent fair yields. The study was made as complete as possible within the limited time, life histories were obtained for most of the pests, and remedies elaborated. The results are now in manuscript and will later appear as a bulletin.

The most destructive pest of sweet potatoes apparently is the stem borer (*Omphisa anastomosalis*), a recent introduction from China. It bores into the stems and kills many plants. It sometimes gets into the potato, in which case the damage is even more serious. It is not much parasitized and is quite common in sweet-potato fields. It would be difficult to control artificially. The leaves of the sweet potato are mined by the larvæ of the tineid moth (*Bedellia orchilella*), and probably by other species of this genus, but this pest is fairly well kept in check by chalcid parasites. The hornworm (larva of the sphinx moth, *Phlegethontius convoluli*) is quite common but not often very injurious; cutworms are said to attack the sweet potato; and there are two leaf rollers (*Phlyctænia despecta* and *Amorbia emigratella*) which damage the foliage to some extent. The common sweet-potato weevil (*Cylas formicarius*) has at times been a very destructive pest and one difficult to control. It breeds in the stems of the common shore plant (*Ipomœa pes-caprœ*), and will always be a menace to the cultivation of sweet potatoes, although actual instances of its infesting sweet-potato fields are few. Another weevil, the West Indian scarabee (*Cryptorynchus batatœ*), is also common in the tuber or rootstock of the sweet potato and at times greatly damages the crop. Among the minor pests may be mentioned the leaf hoppers *Nesosydne ipomœicola* and *Oloha ipomœa*, *Plusia chalcites*, an undetermined Pseudococcus, the Japanese beetle, and a species of Saissetia.

Considerable time has been spent in studying Coccidæ—a group of extreme economic importance in these islands—but no report can be offered on this work. An addition was made to the list of Hawaiian Coccidæ in recording the presence of *Geococcus radicum* Green on roots of mango, koa, and nut grass. The insect was described and figured anew by the writer.[1]

[1] Proc. Hawaiian Ent. Soc., 2 (1910), No. 3, p. 108.

A FIVE-YEAR-OLD AVOCADO TREE, TOP WORKED TO A SELECTED VARIETY BY BUDDING.

REPORT OF THE HORTICULTURIST.

By J. E. Higgins.

The work of this department for the fiscal year dealt chiefly with the avocado, mango, papaya, and citrus fruits. Minor attention has been given to the sweet potato and to a considerable number of miscellaneous subjects which demand recognition in the present stage of Hawaii's horticultural development.

AVOCADO.

The work with avocados during the year may be classified chiefly under four subjects, as follows: Propagation, insect control, disease control, and study of varieties.

PROPAGATION.

Substantial progress has been made in devising means for the successful budding of the avocado. Because of the lack of young nursery stock most of the trials have been in topworking of orchard trees. Plate I shows a tree in the experimental orchard topworked to a valuable variety by means of budding.

The greatest difficulty in budding appears to be not in getting the buds to unite with the stock, but in forcing them into growth. The sap of the avocado oozes out from incisions in the bark, and in budding this characteristic aggravates the difficulties. The sap finds an exit through the T incision, evaporates, and leaves here a crystaline deposit which frequently covers the whole bud, and sometimes the whole bud shield. This is particularly likely to occur before a union has been effected, although it may occur long after. It has been found possible largely to control this trouble, during the period when union is being effected, by wrapping the whole of the stock, in the region of the incision, and thus preventing evaporation.

When a bud has become united to the stock it has proved inadvisable to lop the stock immediately, as is done with citrus and some other budded stocks. The wood is often so brittle in the young portion, where the bud is inserted, as to prohibit successful lopping. If partly cut, it will snap off completely. If a stock is completely cut off, it is likely to die back to the bud and below it before the latter has started into growth.

To overcome these difficulties it has been found advisable to girdle the stock completely, or partly, at a point several inches above the bud, being careful to remove only the bark, so that the upper portion

will not be destroyed. Mr. Holt, who has done most of the actual manipulation of the buds under the direction of the horticulturist is continuing the work with a view of overcoming more completely some of the difficulties which have made the budding of avocados somewhat discouraging.

Inarching is being successfully used for certain types of propagation. It is quite easy to effect a union of scion and stock by this method, which presents a very ready means of bringing seedling varieties into early bearing by placing them on old trees. This may prove to be one of the best means of testing out seedlings whose characters it may be desired to determine, either for practical or scientific purposes.

Some success has been had in growing avocados from cuttings. It has frequently been found in the station experience that avocado cuttings readily form a callus, but do not strike root. The method which has proved partly successful in causing the formation of roots during the past winter consists in packing the cuttings in moist sphagnum moss for several weeks before placing them in the propagating bench. Thus far well-matured wood with gray bark has proved most promising in this work. If cuttings can be made to root readily there are occasions when this means of propagation could be advantageously used.

INSECT CONTROL.

The two chief insect pests of the avocado in the station orchards during the year have been the avocado mealy bug (*Pseudococcus nipæ*) and the larva of the tortricid moth (*Amorbia emigratella*). The latter has caused considerable damage to foliage in the station orchard and to the fruit in gardens of the city. The larva wraps itself up in the young leaves, sometimes sewing together the terminal leaves while opening. It inhabits this place until the food supply is somewhat reduced and then proceeds to another similar locality. Because its attack is upon the very newest growth it is not as easy to control by arsenical poisons as would otherwise be the case. However, frequent spraying with arsenate of lead has considerably reduced the numbers of these insects.

The avocado mealy bug for some years has not required much attention to keep it under control in the station orchard. Practically no spraying has been done for two or three years, and only an occasional tree has been fumigated. There are always some insects of this species in the orchard, but they do not appear to become a serious pest, probably being held in control by ladybirds. It is aimed to foster these by planting, every rainy season, a cover crop of cowpeas, jack beans, or some similar legume, which is subject to the attacks of aphides. These aphides do not disturb the avocado, but multiply

in the legumes and furnish an abundant food supply for numerous species of ladybirds. After this food supply has been cut off, these natural enemies of the mealy bug turn their exclusive attention to the scale insects of the trees.

DISEASE CONTROL.

A fungus disease of the avocado, probably a species of Gloeosporium, has done much damage in many parts of the Territory; in fact, no district has been visited by the horticulturist in which this disease has not been very prevalent. It attacks the leaves, causing them to become a rusty brown color, and frequently causing them to fall prematurely. It also causes the dying back of the twigs and branches and often results in the total destruction of the tree. During the past season, flowers were noticed destroyed apparently by this fungus, the destruction extending into the new wood. When the vitality of the wood has been reduced, it becomes an attractive place for borers.

Work has been begun to test the efficiency of four leading fungicides in the control of this disease. With these fungicides, arsenical poisons have been included, when possible, as a means of destroying the Amorbia mentioned above. The remedies being tried are: Bordeaux mixture with arsenate of lead (6–6–50 formula); resin lime mixture with Bordeaux (formula, 2 gallons resin lime stock to 48 gallons Bordeaux dilute); self-boiled lime-sulphur wash (6–6–50 formula) with arsenate of lead; and commercial lime-sulphur (formula 1–30), with arsenate of lead. It is too early to look for marked results from the use of these fungicides, since the work has been in progress only a short time. It can be said, however, that none of the remedies has produced any serious foliage injury.

VARIETIES.

Mr. Hunn, the assistant horticulturist, has made careful studies of a large number of varieties of avocados for the purpose of ascertaining their merits for commercial or home production. Many very excellent midseason varieties have been found. These, unfortunately, are not the best adapted to commercial growing, because they would reach the mainland when the markets were overstocked with many kinds of Temperate Zone and subtropical fruits. There is, however, a sale for such in limited quantities at high prices even at that season. First-class avocados in sound market condition will sell at that season of the year (June, July, and August) at $2 to $2.50 per dozen in the San Francisco market. The extra early varieties, which could be placed in mainland markets before the 1st of

June, and the extra late varieties which would be marketable after the 1st of November, could be sold in large quantities, as the demand for fresh fruit is better at that time. The four varieties following are of particular merit from one or another of the points of view indicated above:

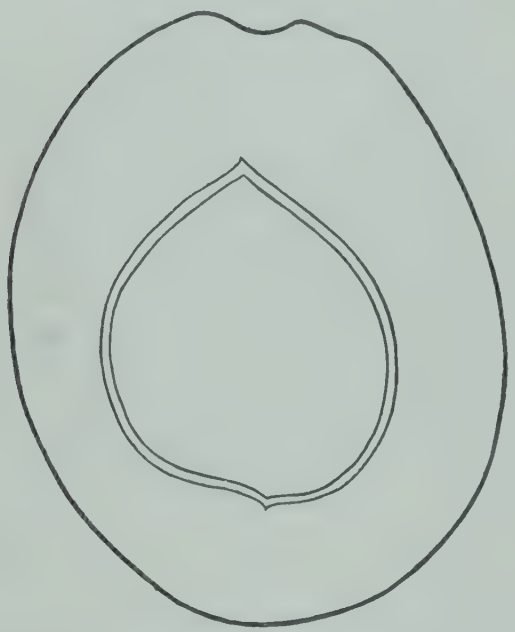


FIG. 1.—Form of fruit and seed of avocado No. 149. About one-fourth natural size.

No. 149 (Fig. 1). About 20 years ago Admiral Beardsley, leaving Guatemala for Hawaii, carried with him a number of avocados for consumption on the way. He saved two seeds, wrapping them in cotton wool and packing them in ice. Arriving in Honolulu, he gave one seed to Judge Wiedeman and the other to Mrs. E. K. Wilder. The former was planted at 1402 Punahou Street, now occupied by "The McDonald," and although both seeds grew, this one is far superior in quality and blooms earlier.

Form roundish to spherical; size medium to medium large; cavity small, shallow, and flaring; stem somewhat slender and very long, varying from 6 to 15 inches in length; surface undulating, very hard; coriaceous and markedly pitted; color dark olive green to purple, with small, very abundant, irregular-shaped yellowish dots; apex a mere dot, slightly depressed; skin very thick and woody, separating freely from the pulp; flesh yellow in color, running into green at the skin, fine grained, oily and somewhat buttery, 75 per cent of fruit; seed fairly large, roundish conical, just a trifle loose in the cavity; flavor rich and nutty. Season July to January.

The tree is quite vigorous, but tends to grow upward rather than to branch out, probably due to confinement. This pear is especially noteworthy, since it will keep for a long time after being removed from the tree. Mr. G. P. Wilder reports that he has kept the fruit for two and one-half weeks after removal from the tree. The tree carried fruit over through the blossoming period of the following season. Height 40 feet, spread 20 feet.

Valuable as a late avocado. Its woody skin should make it a good shipper.

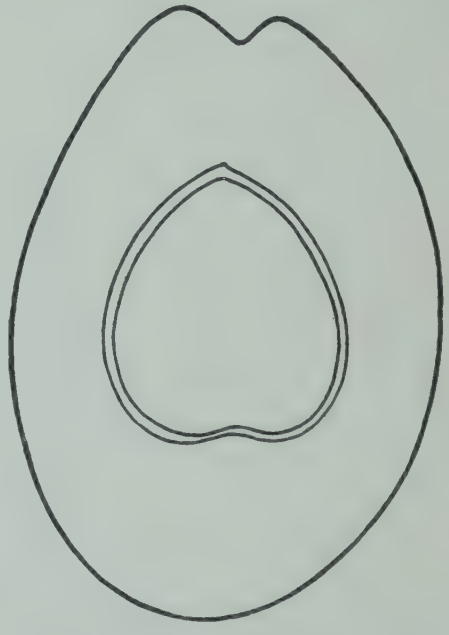


FIG. 2.—Form of fruit and seed of Moanalua avocado. About one-fourth natural size.

MOANALUA (Fig. 2). A chance seedling 19 years of age growing on the estate of Hon. S. M. Damon, Moanalua.

Form pyriform; size small to medium; cavity flaring, deep; stem somewhat short, rather thick; surface undulating, hard, coriaceous, and slightly pitted; color dark green, with medium abundant, small, irregular-shaped yellow-

ish dots; apex a mere dot; skin medium thick, separating readily from the pulp; flesh yellowish in color, running into green at the rind, fine grained, melting and somewhat buttery, 70 per cent of the fruit; seed medium large, conical, fitting tightly in the seed cavity; flavor rich and nutty. Season July to September.

The tree is very vigorous. Height 30 feet, spread 25 feet.

No. 150 (Fig. 3). A chance seedling whose origin and age are unknown, growing near the residence of Charles Renear, Emma Street.

Form pyriform; size small to medium; cavity shallow and somewhat rounded; stem short and medium thick; surface undulating, medium hard, coriaceous, slightly pitted; color green, with reticulate-like markings, with medium large somewhat circular yellowish dots; apex a mere dot; skin very thin, separating readily from the pulp; flesh yellow, melting, but a trifle watery, 70 per cent of the fruit; seed medium large, conical, fitting loosely into the cavity; flavor pleasant. Season middle of May to July.

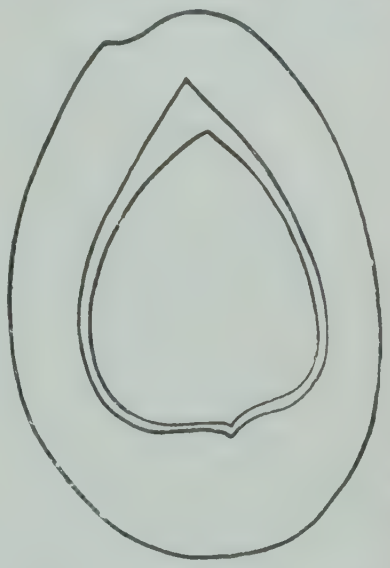


FIG. 3.—Form of fruit and seed of avocado No. 150. About one-fourth natural size.

Valuable because of its earliness. Height 30 feet, spread 20 feet.

No. 145 (Fig. 4). A chance seedling about 15 years of age; origin unknown.

Form pyriform; size small to medium; cavity shallow and somewhat abrupt; stem medium long and quite thick; surface undulating, hard, coriaceous, and slightly pitted and mottled; color green, with small, very abundant yellowish dots; apex a depressed dot; skin quite thin, separating fairly well from the pulp; flesh yellow, running into green at the rind, fine grained, oily, and somewhat buttery, 60 per cent of the fruit; seed very large, conical, fitting loosely in the cavity; flavor rich and nutty. Season September to January.

This tree is very vigorous and symmetrical. Height 25 feet, spread 25 feet.

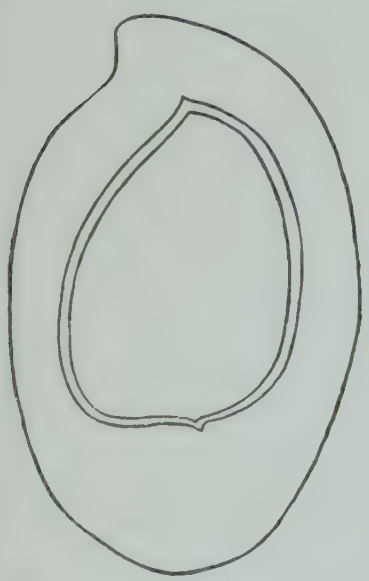


FIG. 4.—Form of fruit and seed of avocado No. 145. About one-fourth natural size.

FERTILIZER TRIALS.

The station orchard, consisting of miscellaneous varieties and many seedlings, makes it impossible to conduct an exact fertilizer experiment, but certain sections of the orchard have been chosen which apparently furnish sufficiently uniform conditions for some simple trials of fertilizers. It is hoped that these tests, conducted in cooperation with the chemical division of the station, will point the way to more definite and accurate experiments when uniform conditions can be attained. From our observations there is some evidence that the excessive use of nitrogenous fertilizers may tend to produce a fibrous fruit.

MISCELLANEOUS STUDIES.

Some studies have been made of the root system of the avocado. Attention has also been devoted to pruning, girdling, and other orchard operations.

MANGO.

PROPAGATION.

The propagation work with the mango has been continued along the lines outlined in previous reports and bulletins. Good use has been made of the method of shield budding the mango.[1] By this means a still larger number of new varieties have been worked in the trial orchard. Quite a number of potted trees have been taken to the orchard and have afforded inarches on some of the older seedling trees. A marked example of the results which may be obtained by this method has come into the station experience during the year. In December, 1908, an Indian variety, Brindabani, was thus grafted upon a strong seedling in the orchard. At the present writing, 18 months later, the new variety is bearing fruits nearly fully matured, others in various stages of development, and also flowers.

TRANSPLANTING.

Opportunity has been afforded for still further testing the possibilities of transplanting large nursery trees. Quite a number of 4 and 5 year old trees were taken up from the nursery and removed to the orchard, in part to test this matter, since it has frequently been stated that mango trees are difficult to transplant. All the trees were severely cut back, leaving only a trunk about 2½ feet above the crown. The transplanting was done in the autumn and early winter, at a time when the trees were not flushing. Some of the trees were removed with naked roots and carefully taken at once to the orchard. Others were taken out with a ball of soil and planted immediately. Still another lot, which had been dug up 15 days previously and had been carefully "heeled in," were planted beside the others. A fourth lot, which had been treated in the same manner as lot 3 except that the naked roots were exposed to the air for an hour or two, was also planted. It has not been possible to detect any difference in the vigor of growth of any of the above lots, all trees having lived and made a good growth.

Mr. E. C. Smith, of Pearl City, Oahu, reports that he at one time removed a mango tree which had been bearing, and though severely cut back even the next year's crop was not lost. It appears, there-

[1] Hawaii Sta. Bul. 20.

fore, that if mango trees are transplanted when not in flush and are severely cut back a large degree of success can be expected in transplanting.

The above results of trials, together with the methods of budding the mango referred to, would seem to place beyond doubt the growing of the mango as nursery stock on a commercial scale

ROOT SYSTEM.

Studies have been made of the root system of the mango by sluicing away the soil and removing the tree with its main roots intact.

INSECT CONTROL.

It has been found necessary to fumigate a few trees in the mango orchard for the destruction of the scale (*Phenacaspis eugeniæ*) and also a few for the Florida red scale (*Chrysomphalus aonidum*). When the mango tree is not flushing it can be fumigated with hydrocyanic-acid gas in doses equal to those used on citrus trees without injury to the foliage.

A red-banded thrips (*Heliothrips rubrocinctus*) should be mentioned in this connection. These were found in large numbers on young mango seedlings in the greenhouse, and were causing very serious damage. They were referred to the station entomologist, who kindly had them identified as above. Those who are starting mango plants in greenhouses or in a sheltered place should be on the lookout for these pests. They may be distinguished as small, rather wedge-shaped bodies, very beautifully marked with red bands. It has not been found difficult to destroy them by dusting the plants with finely powdered sulphur after they have first been sprayed with water so as to retain the powder.

The species of Amorbia referred to elsewhere as a pest of the avocado has also proved destructive to the mango flowers and to some degree to the young leaves. Arsenate of lead has been found effective in destroying the larvæ.

The large carpenter bee (*Xylocopa aneipennis*) did considerable damage to young mango buds in the propagation experiments until its work was discovered and prevented. The bee seems to find an inviting place for boring just above the bud on the bud shield, and in many instances bored through the shield into the old wood of the stock, causing injury and sometimes destruction to the bud. It has been found easy to control this injury by placing grafting wax in all the incisions, leaving only the bud and a small portion of the shield exposed. This should be done when the bandage is removed, if injury of this kind is experienced.

DISEASE CONTROL.

The fungus (*Glœosporium mangiferæ*) does great injury to the mango crop in Hawaii, destroying the flowers and much of the fruit. It has been stated in earlier reports that this disease can be held in control by Bordeaux mixture. Experiments, however, have been undertaken with other fungicides for the control of this fungus. The same series of trials, as outlined elsewhere for the control of the diseases of the avocado, is in progress in the mango orchard.

VARIETIES.

There is now quite a large number of varieties in the station orchard. Some of these are introduced varieties from India and elsewhere, and others are valuable local seedlings. The list of varieties now growing at the station is as follows:

Alphonse, Accession Nos. 1072, 1158, 2014, 2101.

Douglas Bennett's Alphonse, Accession Nos. 278, 1161, 1370, 1371, 1926, 1933.

Ameeri, Accession No. 2100.

Arbuthnot, Accession No. 1943.

Bombay Yellow, Accession Nos. 1029, 1921.

Brindabani, Accession Nos. 1202, 1372.

Cambodiana, or Saigon, Accession No. 260.

Crescent, Accession Nos. 1945, 1946, 1948.

Divine, Accession No. 2108.

D'Or, Accession No. 2109.

Cowasjee Patel, Accession No. 2485.

Faizan, Accession No. 1200.

Fijri Long, Accession No. 1920.

French, Accession Nos. 1962, 1963.

Gay, Accession No. 1940.

Herbert's No. 9, Accession Nos. 1960, 1967, 1968.

Jamshedi, Accession Nos. 1201, 1373.

Java, Accession Nos. 1949, 1950, 1953.

Julie, Accession No. 2102.

Lady Finger Chutney, Accession No. 1271.

Mazagon, Accession No. 2484.

Mulgoba, Accession No. 2093.

Paheri, Accession No. 2094.

Peters No. 1, Accession No. 2092.

Pirie, Accession No. 1159.

Sharhati Black, Accession No. 1203.

Strawberry, Accession No. 1533 (local seedling).

Strawberry, Accession No. 1944 (from Section of Seed and Plant Introduction).

Sandersha, Accession No. 1074.
Totafari, Accession No. 279.
Smith Wootten, Accession No. 1985.
Wootten Chutney, Accession No. 840.

PAPAYAS.

MONŒCIOUS AND DIŒCIOUS TYPES.

Investigations have been begun with papayas which are of interest because of their bearing upon theories of plant breeding and also because of their practical aspect. It is a well-known fact that papayas are extremely uncertain in the reproduction of their characters. Selection has been practiced to a considerable degree by the growers of this fruit, but seeds from the best fruit are liable to produce trees of very indifferent character. The reasons for this may be suggested by a study of the different types of the papaya. There are two extreme types and several intermediate forms. First, there is the strictly diœcious type. In this, the fruit-bearing tree produces pistillate flowers only. The staminate, or "male," tree produces staminate flowers almost exclusively but with an occasional perfect flower which is capable of producing fruit. Most of the staminate flowers have a rudimentary ovary and style, but are without any stigma, and are utterly incapable of fruit production. The fruit of the pistillate tree of this type is usually ovoid or more or less rotund in shape.

The second type is monœcious. Every tree produces fruit. The trees produce two forms of flowers; first, a perfect flower, and, second, a staminate flower. In the axil of each leaf there is usually a small flower cluster, only a few inches in length, which contains at least one perfect flower and one or more staminate ones. This perfect flower is quite different in shape from the pistillate flower of the diœcious type. Its pistil is much more elongated, being almost cylindrical throughout a portion of its length. The stamens are usually situated on the inner walls of the petals, about midway of their length, with the anthers surrounding the lobes of the stigma. The fruit of this type differs from the fruit of the diœcious tree in the same way as the pistils. The fruit of this monœcious type is usually elongated, and is generally spoken of as the "long" papaya.

Between these two types, the one almost completely diœcious and the other monœcious, there are many intermediate forms which may have arisen through the crossing of these two. For example, there are in the station collection trees which produce three types of flowers, namely, staminate flowers and two forms of perfect flowers. The one form of perfect flower corresponds precisely with the per-

fect flowers of the monœcious type, spoken of above. The other perfect flower has an ovary in shape like that of the pistillate flower of the diœcious type, and produces a fruit more nearly resembling this type. Its stamens, however, are variously located; they may be found at times arising from the base of the petals; or at times the anthers are attached to the lobes of the ovary, the latter condition usually resulting in a deeply furrowed or distorted fruit. One tree in the station collection produces only staminate flowers, but is peculiar in the fact that these flowers are borne close to the stem and in the axils of the leaves, while staminate trees of the ordinary diœcious type produce their flowers in long pendant clusters.

BREEDING PROBLEMS.

What is the bearing of these facts to a practical plant breeder who may wish to produce a papaya of a good variety whose characters will be more or less stable in reproduction? Suppose that the diœcious type is used in selection, as has been the case usually. Seed from this fruit will necessarily be a cross of two individuals. The characters of the female plant are known, but those of the male plant are utterly unknown. The parent stock from which both came may be known, but since there is wide variation in the fruit of two pistillate trees from the same stock it is reasonable to suppose that there will be the same wide variation in the male or staminate trees. The variation between the pistillate trees can easily be determined because their fruits are in evidence and can be tested; but the characters which are inherent in the male or staminate tree, and which will be transmitted by it to its progeny, can be determined only through the long process of actual hand-pollination, the sowing of the seed thus produced, and the testing of the fruit. Even then, what portion of its excellent or indifferent qualities it may have inherited from its male parent can not be known. Furthermore, the difficulty becomes aggravated by the fact that papaya trees usually degenerate after a very few years. At least, pistillate trees usually fail to produce good fruit after a few years of growth, although they may continue to produce indifferent fruit for many years. Therefore, even if the inherent characters of the male or staminate tree could be determined with reasonable accuracy, before any such determination could be made the tree would have become too old to be in a reliable state of virility, if it degenerates as rapidly as the pistillate tree. It therefore appears reasonable to suppose that the process of producing a stable variety of good qualities by the use of this diœcious type would be extremely long and tedious. The hope, therefore, must lie in the use of the monœcious type. Here it is possible to select an individual of known qualities. This may be used as the sole parent stock, or may be combined with another parent of known

qualities. Of course, either may at the start be of uncertain reproducing power. That is to say, what mixtures of blood there may be in the individual at the start may not be known; but through repeated selections and the elimination of undesirable characters, it should be possible to produce a reasonably stable variety, provided, of course, that the stock is kept pure by constantly avoiding cross-pollinations, a process which is necessary in all plants reproduced by seed and whose flowers are subject to accidental cross-pollination.

A further practical difficulty in the use of the diœcious type, from the standpoint of the papaya grower, as well as the breeder, is the fact that a very large proportion of the trees from any given lot of seed are liable to be staminate, or males, and therefore useless, only a few trees being necessary to pollinate all the pistillate trees. It is impossible to distinguish the staminate from the pistillate trees in the early stages of their development. Various theories have been advanced to distinguish these two sexes before the trees have flowered, and it has been reported that staminate trees have been caused to produce pistils and fruits by beheading them. None of these means, however, has proved to be successful from a practical standpoint. Therefore, in any papaya orchard planted with the diœcious type, a very large percentage of the trees must be cut out after they have grown almost to maturity, resulting in unevenness and irregularity in the orchard and much loss of time and space. For this reason, together with the difficulties of breeding, the diœcious type will likely be largely eliminated.

Returning to the subject of papaya breeding, it is not yet known what the result will be from crossing the pistillate tree of the diœcious type with pollen from a tree of known character of the monœcious type. As has been indicated above, there are several intermediate forms which appear to be the result of crossing the monœcious and the diœcious types; but, apparently, there is no definite knowledge on this point. These intermediates may have resulted from the accidental crossing of the monœcious type with pollen from the staminate tree of the diœcious type. It may be possible to make some of these crosses without giving rise to an undue number of male or staminate trees.

This work which is only in its incipiency offers a wide and interesting field for investigation.

CITRUS FRUITS.

INSECT CONTROL.

No new problems have been undertaken with citrus fruits. The orchard is being maintained and has afforded opportunity for the further testing of fumigation with hydrocyanic-acid gas for the con-

trol of the mealy bug (*Pseudococcus filamentosus*) and other scale insects. This method of control has proved the most effective means which has yet been tried. It is extremely difficult to control *P. filamentosus* because it is so vigilantly attended by ants. It has been found possible to destroy the insects on the trees by fumigation if the soil is removed from the crown so as to expose the insects to the gas. Reinfestation, however, takes place more rapidly than in the case of the Florida red scale (*Chrysomphalus aonidum*) and the purple scale (*Lepidosaphes beckii*).

The caterpillar (*Amorbia emigratella*), referred to as a pest of mango and avocado, has required considerable attention. After consultation with the entomologist, treatment was begun with arsenate of lead. Because of the habit of this insect, in wrapping itself up in the newest growth, it becomes difficult to poison it with arsenical sprays. The spraying was repeated several times. The insect now appears to be fairly well under control.

NEW VARIETIES.

Several new varieties of oranges, pomelos, and lemons have been introduced during the year. A number of the newer Florida pomelos have been budded into the station orchards and nurseries. The station agronomist, Mr. F. G. Krauss, while traveling in Japan and China, collected some of the best pomelos of those countries, including the famous Amoy variety. Bud wood was brought back to Hawaii, and some of it arrived in fair condition. Buds were inserted in a number of stocks at the station, but none has succeeded. The buds "took," and a few started into growth but afterwards failed.

A number of citrus varieties have been received from Mr. Gerrit P. Wilder while traveling through the Orient and southern Europe. These have been worked into the nursery by both budding and grafting and are making good progress.

SWEET POTATOES.

In a bulletin of this station,[1] attention was called to the possibility of a profitable industry in the shipping of sweet potatoes from Hawaii to the mainland of the United States and Canada during the season when the market there is practically bare, because the home-grown product is out of season. All these markets are accustomed to the yellow variety, known on the Pacific coast as Merced Sweet. This local name has arisen from the fact that Merced is the center of the most successful sweet-potato cultivation. The variety is that usually known in the East as the Jersey Sweet. It was also stated in the

[1] Hawaii Sta. Bul. 14.

bulletin referred to that the red varieties commonly grown in Hawaii are unfamiliar to those markets. This left the question open as to whether Hawaiian sweet potatoes of the ordinary varieties would find a ready sale on the mainland.

This matter has been tested by the growing of a number of varieties and the marketing of the same in San Francisco. The first two shipments included several red sorts as well as the Merced. All varieties sold readily at 8 cents per pound. Later reports, however, brought out the fact that the dealers found the consumers prejudiced against the red color and refused to buy them. It would seem to be unwise for Hawaiian shippers to attempt to break down this prejudice, and attention should be given to the growing of the Merced variety, with which the market is familiar. Roots of this variety are being distributed by the station.

These trial shipments confirm the earlier belief that sweet potatoes of suitable varieties will bring high prices when the California product is out of season.

It seems hardly necessary to state that 8 cents per pound should not be expected on large shipments. The commission house which handled these trial lots advised the station as follows:

"If you can succeed in producing the yellow variety of medium to large size, we are confident they can be distributed here during our late spring and early summer season so as to make them quite profitable to you. By this we mean from 4 cents to 5 cents per pound with a possibility of higher prices for a portion of them."

The season of shipping is important. California sweet potatoes are out of season from about May 15 to August 1. This is the period during which Hawaiian-grown sweet potatoes should arrive. In some years it may be found possible to put them in a little earlier.

MISCELLANEOUS NOTES.

Quite a large amount of miscellaneous work presents itself from time to time, and miscellaneous plants of different species demand some attention. A few of these may be mentioned.

GARCINIA MANGOSTANA.

The mangosteen has one or two bearing trees to represent it in Hawaii. Two fruits, which represented half the crop of one of these trees, were secured a year or two ago. One of the two fruits contained a seed, which was planted and has made rather an indifferent growth, but has done better than plants which have been introduced in Wardian cases.

There are one or two other species of Garcinia in Hawaii which appear to do well. It has seemed probable that the mangosteen might do better in Hawaii if budded on other stocks. Mr. E. W.

Jordan secured bud wood of the mangosteen from Mr. Francis Gay, of Kauai, and the writer, in cooperation with Mr. Jordan, placed buds of these on the *Garcinia xanthochymus*, known locally as the "African mangosteen." This work was performed only a few weeks previous to the present writing, and it is therefore too early to know whether any successful results will arise.

CARISSA ARDUINA.

Carissa arduina (Ac. No. 1764, S. P. I. No. 11734), which is a South African fruiting shrub, was introduced from the Section of Seed and Plant Introduction of the Department of Agriculture in the year 1905 under the number indicated above. The four plants received at that time have all made a vigorous growth, but have exhibited decided differences in character. Two of the plants have proved heavy producers and two have been rather shy bearers. Plate II, figure 1, shows one of these trees in fruit.

The shrub is useful as a hedge plant because of its dense growth and its strong thorns, which render it practically impassable, and also for its very beautiful red fruits, which are about the size of a plum. The latter may be eaten from the hand or may be used in the manufacture of jellies.

Selections are being made of the best fruits from the two best trees. About 2,000 plants are now in the greenhouses and will be ready for distribution within a few months. There remains a large crop of fruit, affording the opportunity for still larger propagation and distribution. It is believed that the plant will be useful as a hedge to surround fruit gardens which are subject to the attacks of nocturnal visitors.

After the plants have become well established in the propagating houses they appear to be free from all serious insect attacks in Hawaii. They are subject to the attacks of the scale, *Saissetia hemispherica;* but this is so successfully parasitized in Hawaii by *Scutellista cyanea* and other parasites that it has not proved a pest on Carissa.

LITCHI (NEPHELIUM LITCHI).

A number of the plants of this species, introduced from China in 1908, have made a fair growth, although severely attacked by the Japanese beetle and by the scale (*Saissetia nigra*). The latter can readily be controlled by fumigation, and it is not believed that the Japanese beetle will prove a serious pest after the trees have grown to large size. The seedling litchis that are growing in various parts of Honolulu are not seriously attacked by this pest.

The litchi, being a slow grower and requiring usually from 15 to 20 years to come into bearing, when grown from seed in Hawaii, it

FIG. 1.—CARISSA ARDUINA, A VALUABLE FRUIT AND HEDGE PLANT.

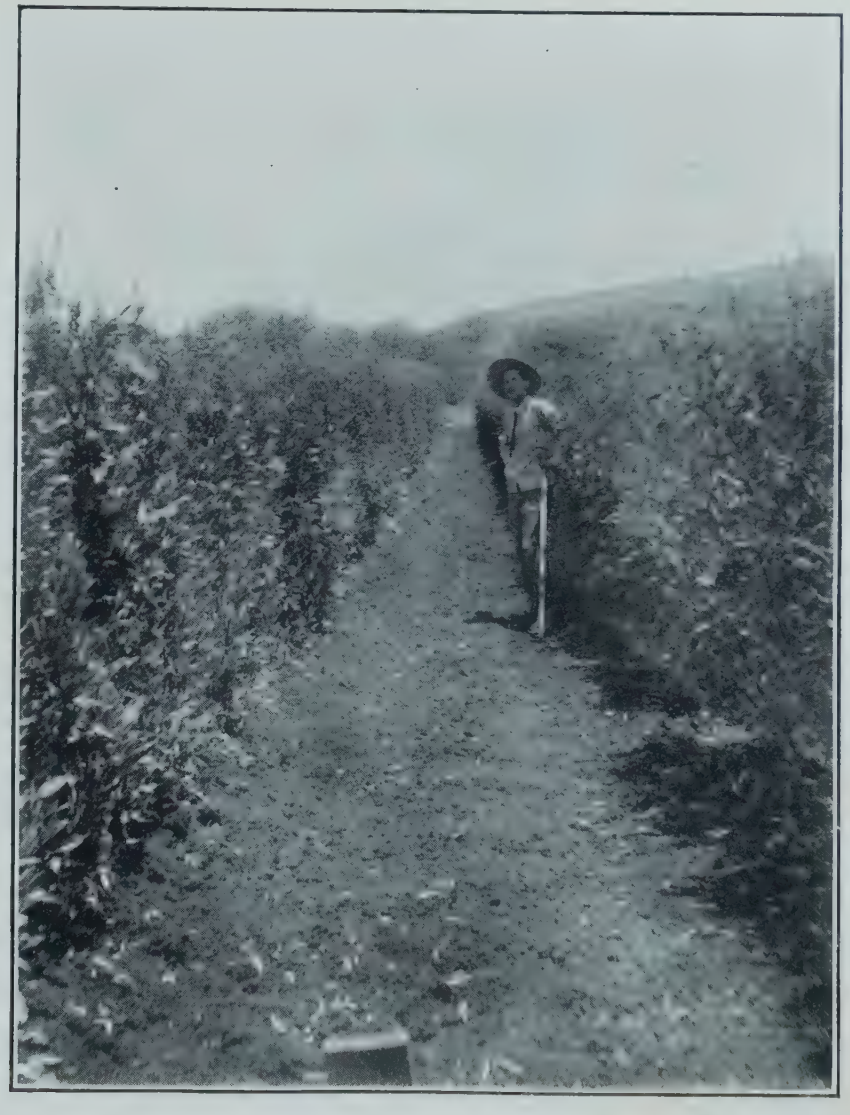


FIG. 2.—PIGEON PEAS AS A WINDBREAK FOR NURSERY STOCK.

has been thought desirable to attempt the growth of this tree on the more vigorous growing stock of the longan (*Nephelium longana*). Attempts are now being made to graft scions of these imported varieties on seedling longans by the inarching method.

DECIDUOUS FRUITS.

As stated in previous reports, the Parker ranch has undertaken rather extensive experiments in the growing of deciduous fruits and grapes. In these experiments the station has taken a considerable interest and has cooperated so far as possible. In February, 1910, the horticulturist again visited the chief of these plantings at Waiki, on the island of Hawaii, at an elevation of about 4,500 feet. Instruction was given in pruning, insect control, and the general care of the orchards, and observation was made of the progress of the different kinds of fruits being grown. This being the winter season, it was impossible to judge of the fruits themselves, except in the case of a few apples which had been kept through the winter. These were of good size, and those that were not withered by exposure to the air were crisp and of good flavor. Apples have made a very satisfactory growth, except those planted the previous season, which was one of unusual drought. Established trees seemed to do well, notwithstanding the prolonged dry weather. Peach trees also made a satisfactory showing and were reported to have produced good fruit. They were well supplied with fruit buds. Cherries have not succeeded, and plums and pears can not yet be said to have proved a success. Grapes of several varieties, including the Tokay and the Muscat, have made good growth and are reported to have produced fruit in 1909. In general, it may be said that the outlook is promising for the production of apples, peaches, and grapes in this locality.

TREE TANGLEFOOT.

This sticky substance has been used on the deciduous plantings, as well as on the station trees, for the purpose of preventing ants, cutworms, and other injurious insects from ascending the trees. Under some conditions it has proved quite effective if the surface is kept renewed by repeated agitations, or combings. A serious result appears to have followed the use of this remedy at the Waiki orchards on peach trees. It had been applied directly to the bark of the trunk and had remained for many months. Wherever it was found remaining upon the peach trees they were dead. Examination of the bark of the trunk under this sticky preparation revealed injury of the tissue and a discoloration which extended completely around the trunk. This remedy has been applied to the bark of a number of trees at the experiment station without any apparent injurious effects, but

it has not been so applied to peach trees. It is, therefore, recommended that precaution be taken in its use, and that in the case of peach trees, particularly, it should not be applied directly to the bark. A broad bandage, made of cheap cotton dipped in hot paraffin, may be wound spirally around the trunk of the tree and tied at the top by splitting into two parts like a surgeon's bandage. To this the sticky substance may be applied without injury. If the cotton is not too strong there will be little danger of girdling.

PIGEON PEA.

The pigeon pea (*Cajanus indicus*) is being tested as a temporary wind-break and as a permanent wind-break for nursery stock. In two or three months from seed, it affords considerable protection to small growth, and in six or seven months attains a height of 6 feet, and thus makes a good wind-break for young citrus, avocado, and mango seedlings. For this purpose it is planted quite close in the row, the plants standing only 3 or 4 inches apart. In citrus nurseries, the rows of these fruit trees are being tried at 6 feet apart, and a row of pigeon pea is being planted midway between the citrus. Where land is cheap, it would be better to increase the distance between the rows. By this means the wind-break could remain as long as the trees might be in the nursery. Plate II, figure 2, shows the pigeon pea protecting young citrus seedlings.

RATTAN PALMS.

Several species of this palm, Dæmonorops, have been introduced from Java. About 200 of these palms have been distributed in different parts of Hawaii where it was thought they would be most likely to succeed. These plants afford a fiber which is used in the shipping of tobacco, and if successful in Hawaii should be a valuable aid to the tobacco industry.

BOUGAINVILLÆA DISEASE.

A disease of the bougainvillæa has been observed during the year on both the species *B. spectabilis* and the species *B. refulgens*. This is a sort of crown rot which causes the decay of the bark and wood near the ground. A large vine of *B. spectabilis* was treated by the removal of the dead bark and the washing of the wound with carbolic acid and water, after which paint was applied. The plant appears to be regaining vigor.

REPORT OF THE CHEMIST.

By W. P. Kelley.

During the past year the chemical department has been engaged mainly in soil and fertilizer investigations along the lines suggested in the previous report. In addition, some attention has been given to a study of the composition of pineapples.

PINEAPPLE SOIL INVESTIGATIONS.

In the report for 1909 the writer pointed out some of the conditions that exist in the pineapple districts of Oahu and drew attention to their peculiarities. Investigations during the past year have further emphasized the necessity of a more intelligent management of these soils. Frequent requests by farmers for assistance and advice, together with numerous observations by the writer, have led to the conviction that the time has already arrived when special efforts must be put forth by the farmer if profitable yields of pineapples are to be maintained. The pineapple industry, important as it has become, is still in its infancy in Hawaii, and while continuing to hold out great promise, failure, or only partial success, has resulted in numerous instances. This fact, together with the scientific interest that naturally arises in connection with soils of such abnormal characteristics, justifies a thorough study of all the factors that influence the ultimate fertility of this land.

In numerous instances the application of various fertilizers in liberal quantities has not given satisfactory returns, and an increasing number of planters are realizing that something more than the addition of available plant food is demanded in their fields. The lack of drainage is evident, and in many instances a poor mechanical soil condition is apparent. With satisfactory yields on virgin soil the growers in many instances have failed to adequately appreciate the importance of maintaining what is called "condition" in the soil. In the main the land is under short-term lease, and the principal idea from the beginning of this industry has been to get out of the land a maximum crop at a minimum of cost, with little concern for the ultimate maintenance of the soil.

The work of this department in this connection has been directed along lines which are calculated to show the fallacies of the prevailing system and to secure a scientific basis for rational and permanent conservation of the soil. Looking to this end a series of field and laboratory investigations are under way which have already

resulted in data of scientific interest and of practical value, and when completed ought to enable the farmer to adjust his farm management so as to secure both profit from his efforts and a perpetuation of his business.

It is not considered necessary at this time to detail these investigations, as it is hoped to present this work in its entirety later in the year. The work is being directed toward a study of the effects of aeration, and the chemical and physical changes induced by continued cultivation are being studied in a systematic way. The nitrifying power of the soils, the decomposition of humus, and the physical and biological changes which develop at remarkable rates under the conditions that prevail are being given due consideration.

On Oahu, as previously pointed out,[1] the pineapple soils may be roughly classified as manganiferous and nonmanganiferous. The former, on account of their extreme abnormality, have received considerable attention. The extent of the black manganiferous soil is considerably greater than had been anticipated, and comprises an important part of the pineapple sections of this island. While the areas that contain 4 or more per cent of manganese are ill suited to pineapple growth, the results already obtained indicate that the areas which contain an intermediate percentage of this element may, by the use of suitable fertilizers, be cultivated in pineapples with fair success. The physical properties of the manganiferous soils are superior to those of the nonmanganiferous areas, and drainage is much better on these areas. Consequently if the toxic effects of manganese can be overcome, their cultivation in pineapples will be more permanent.

In one of the manganiferous fields a fertilizer test has been under way for sometime, and while some of the plants made fairly normal growth during their first year's development, with the return of winter and its incident low temperatures the pineapples became yellow and abnormal. Some of the plants, however, have partially regained a normal appearance during the warm weather of the past few months, and are now in full fruit. The plants treated with dried blood or ammonium sulphate, superphosphate or reverted phosphate, and sulphate of potash have from the first greatly exceeded all others, and while the yields will not be entirely satisfactory it suggests a possible treatment for soils that contain more limited quantities of manganese. This soil appears to be greatly benefited by the application of soluble phosphates,[2] although the chemical analysis shows that it contains a rather high percentage of this substance. Not all forms of phosphates, however, are effective. Basic slag produces an increased tendency to a yellowing of the plants, and usually results in poorer yields than no treatment.

[1] Hawaii Sta. Press Bul. 23.

[2] See Agr. Gaz. N. S. Wales, 21 (1910), No. 5, pp. 437, 438.

The popular idea concerning the black manganiferous soils has been that they are sour and therefore in need of lime, but chemical analysis has proven this view to be incorrect, and the application of lime to these soils almost universally results in the development of a more intense yellow color in the plant and its subsequent failure to produce fruit. Basic slag is known to contain free lime, and it is likely that its injurious effect may be traceable to this substance.

A thorough study of the solubility of manganese and the influence of fertilizing substances on its solubility, the form in which the manganese exists in the soil and its relation to pineapple failure, and the influence brought about by the growth of pineapples on the form of the manganese in the soil, the influence of manganese on nitrification, and the physiological functions produced by this substance in the pineapple plant have received considerable attention.

Other crops have been grown on this type of soil in pot cultures with varying degrees of success. Some of these showed abnormal appearances, especially during the first two months of growth. Cereals seem especially sensitive to an excess of manganese. Legumes, although showing normal root tubercles, grew poorly. The lower leaves turned brown and fell away. Cotton and root crops seem less sensitive to this substance than other plants. In practically all plants grown in this type of soil peculiar color appearances were developed, indicating that it reacts in some way on the chlorophyll. In some instances the chlorophyll is destroyed; in others, etiolin or xanthophyll are developed instead of the green coloring matter.

These experiments will be repeated during the coming year and other crops tried and a further study of the physiological functions performed by manganese will be made.

In connection with the pineapple soil investigations on Oahu, some attention has been devoted to a study of the soils in pineapple sections of Maui, where different soil and climatic conditions prevail. Also, soil samples from Kula, the Parker ranch on Hawaii, and the Nahiku rubber district have been examined and some interesting results obtained.

RICE INVESTIGATIONS.

The fertilizer experiments with rice have been continued and some remarkably concordant results obtained. On account of the unreliability of a single year's test with fertilizers, the results of these experiments have not been published. It is customary with the Chinese rice growers in the islands to cultivate the same land in two crops of rice per annum, and where fertilizers are used generally only one application per annum, and that to the spring crop, is made. With the view of determining the residual effects on the fall crop from the spring application, the original plats in our experiments

have been divided into two parts, one of which received an application to the spring crop only, the other the same application to both crops. These experiments have now been carried through three crops and preparations are now under way for the fourth. It is intended to make this a continuous fertilizer experiment, with the view of determining whether it is possible by the use of fertilizers to obtain satisfactory yields under continuous cultivation of rice. A rotation experiment, involving the use of fertilizers, is also being made. In addition, a series of plats, to which different forms of nitrogenous fertilizers were applied, was laid out and some very interesting results obtained. Some experiments[1] were made previously, which indicated that ammonium sulphate is the most economical form of nitrogen for rice culture. A duplication of these results has been obtained. The yields from the plats treated with nitrate of soda have consistently fallen far short of the yields obtained from the use of ammonium sulphate. This observation has led to a detailed investigation of the absorption of nitrogen by the rice plant.

In pot cultures, under strict chemical control, various forms of nitrogen have been applied and some remarkably interesting results obtained. Where the rice has access to nitrates, only very poor growth has resulted; whereas ammonium compounds have resulted in vigorous development. These experiments are being repeated and will likely form the basis for a publication later in the year.

The original practice of applying fertilizers when the rice is about two-thirds grown gave rise to a study of the absorption of nutrients by the rice plant at its several stages of growth. This investigation was carried through two crops with concordant results, and the complete data bearing on this subject have been published.[2] From the results obtained it would seem that the practice of late applications of fertilizers should be abandoned. A large percentage of the substances absorbed from the soil is taken up by the rice plant during its early growth, and greater economy is sure to follow the application of fertilizers before planting than can be obtained from making the applications at the time usually practiced. In connection with this investigation it has been shown that the composition of the rice plant may be materially affected by the application of soluble fertilizers; especially is this fact noticeable during the early development of the plant.

FERTILIZER EXPERIMENTS WITH COTTON AND RUBBER.

As announced in the previous report, two fertilizer experiments have been made with cotton. These are being continued with prom-

[1] Hawaii Sta. Rpt. 1907, p. 83.
[2] Hawaii Sta. Bul. 21.

ising results. The yields of the first crop were, in some instances, more than three times as great on some of the fertilized plats as on the checks, and the appearance of the cotton at present indicates a similar influence in the second crop. The upland soils of the islands for the most part are lacking in available phosphates, due largely to the insoluble nature of the soil phosphates. Some attention has been given to a study of the solubility of phosphates in different types of soils,[1] and the results thus far obtained indicate that the phosphoric acid of the soil is largely combined with iron and alumina as basic phosphates, and hence insoluble.

A fertilizer experiment with rubber was also begun, but sufficient time has not elapsed to draw conclusions regarding the effects. Fertilizer experiments previously made with this crop were limited in number and no extensive results have been published. The slow growth of latex-bearing plants suggests the importance of a practical means of hastening the time of commercial tapping. In this experiment not only the increased growth of the trees is being measured, but the rate of latex flow and the percentage of rubber obtained therefrom will be noted. The soil on which this experiment is located is rich in humus, but inadequately aerated, as is shown by the fact that practically all the iron compounds therein are in a ferrous state, which can not be considered desirable at least. An increase in aeration, due to cultivation, has already been shown to produce an enormous increase in the growth of the rubber trees, and it is hoped at a later time to make a systematic study of this point.

THE COMPOSITION OF PINEAPPLES.

The composition of pineapples grown in other localities has been pointed out by several investigators. In a study of pineapples from Florida, the West Indies, Bahama, and Singapore, Munson and Tolman[2] showed that neither the variety nor the locality in which the fruit is grown exercises any marked influence on its sugar content, although the ratio between reducing sugars and sucrose in a given variety was shown to vary considerably. One pineapple of the Smooth Cayenne variety, for instance, was found to contain 3.17 per cent reducing sugars (calculated as invert sugar) and 7.51 per cent sucrose, while another of the same variety contained 9.75 per cent reducing sugars (calculated as invert sugar) and only 2.98 per cent sucrose. Some analyses were recorded which showed abnormally low percentages of sugar. This fruit was shipped a considerable distance before being analyzed, and irregularities in composition, as pointed

[1] Jour. Indus. and Engin. Chem., 2 (1910), No. 6, p. 277.

[2] U. S. Dept. Agr., Bur. Chem. Bul. 87, pp. 31–38; Jour. Amer. Chem. Soc., 25 (1903), No. 3, pp. 272–280.

out by the authors, may, in part, be traceable to differences in the degree of ripeness at the time of gathering.

Recently Blair and Wilson [1] made an extensive study of the composition of pineapples as affected by the use of fertilizers, and pointed out some interesting results. No extensive investigation of the composition of Hawaiian pineapples, however, has been published, although this fruit is generally conceded to be superior in quality to that grown in most localities.

The Smooth Cayenne is almost the only variety grown in Hawaii, and on account of inadequate shipping facilities and the prevalence of certain fungi a large percentage of these pineapples are used for canning purposes. The fruit for canning is allowed to ripen thoroughly in the field; that used for fresh fruit shipment, on the contrary, is usually gathered just before the true ripening process begins. Some shippers maintain, however, that pineapples one-third ripe may be shipped as satisfactorily as the green fruit.

For the purpose of determining some of the facts regarding the composition of pineapples as influenced by the stage of ripeness at which they are gathered, a number of analyses have been made. The methods employed in this work are essentially those given under the Official Methods for the Analysis of Fruits and Fruit Products.[2] The reducing sugars were determined by the volumetric Fehling solution method; sucrose by double polarization, acidity by direct titration with tenth-normal potassium hydrate with the aid of phenolphthalein. The acid of pineapples is largely citric, but is expressed here as sulphuric. The total hydrolyzable carbohydrates were determined by digesting for two hours 50 grams of the crushed fruit with strong hydrochloric acid (sp. gr. 1.125), cooling, neutralizing with caustic potash, completing to 250 cubic centimeters, and filtering. Reducing sugars in the filtrate were determined by the use of the volumetric Fehling solution method and the results expressed as invert sugar. Nitrogen was determined by the ordinary Kjehdahl method and the solids in the juice were calculated by the use of the tables of H. Ellion from the specific gravity of the juice. Fiber was determined by the usual method for fiber determination in feeds.

The fruits used in this investigation for the most part were gathered from the field by the writer, and the stage of ripeness in every instance was noted, thus largely eliminating uncertainty as to this point. The analytical determinations for the most part were duplicated with concordant results. At this point thanks are extended to the growers in the several districts for their cooperation in this work.

[1] Florida Sta. Bul. 101.

[2] U. S. Dept. Agr., Bur. Chem. Bul. 107 (rev.), p. 77.

The following table shows the composition of pineapples that ripened normally in the field:

The composition of normally ripened pineapples.

Localities.	Serial No.	Nitrogen.	Acidity as H_2SO_4.	Reducing sugars calculated as invert sugar.	Sucrose.	Total sugars.	Polarization.		
							Direct.	Invert.	Temperature.
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*°V.*	*°V.*	*°C.*
Wahiawa		0.06	0.66	3.92	6.78	10.70	5	−3.6	31.7
Do	101	.....	.56	3.94	7.97	11.91	6.4	−3.7	32
Do	105	.09	.43	5.10	7.54	12.64	5.8	−3.8	30.5
Do	110	.09	1.03	4.72	9.88	14.60	7.4	−5.1	32.3
Do	111	.07	.86	5.18	10.05	15.23	8	−4.7	32.7
Do	112	.07	.99	4.59	10.12	14.71	8.4	−4.4	32.3
Do	113	.....	1.06	3.50	8.47	11.97	6.6	−4.2	30.3
Do	114	.09	.71	4.12	6.93	11.05	4.9	−3.9	31.4
Do	115	.07	.82	3.14	7.15	10.29	5.3	−3.8	31
Do	102	.....	.53	3.84	8.36	12.20	6.9	−3.7	31.5
Ahuimanu	106	.08	1.05	3.86	9.45	13.31	7.7	−4.3	31.4
Do	107	.09	1.16	4.18	8.40	12.58	7.1	−3.6	30.8
Do	108	.08	.63	2.78	7.36	10.14	5.4	−4	30
Do	109	.09	.75	3.56	8.12	11.68	6.3	−4	31.7
Haiku	140	.....	.45	4.35	6.08	10.43	4.2	−3.5	32
Do	141	.....	.68	4	6.97	10.97	4.9	−4	30
Do	142	.....	.63	4.87	6.47	11.34	3.9	−4.3	30.2
Do	143	.....	.65	4.85	6.85	11.70	4.6	−4.2	28.6
Do	144	.....	.61	5.55	6.03	11.58	4	−3.7	30
Average	.....	.08	.75	4.22	7.84	12.06	.....	.....	.....

The above data show that Hawaiian pineapples vary considerably in composition. In general the acidity increases with the sugar content, and the average of the total sugars is about equal to that of pineapples from Florida and the West Indies.

In the following table is shown the composition of green pineapples, gathered just before the beginning of the ripening process:

The composition of pineapples just before the beginning of the ripening process.

Localities.	Serial No.	Acidity as H_2SO_4.	Fiber.	Solids in juice.	Hydrolyzable carbohydrates.	Reducing sugars calculated as invert sugar.	Sucrose.	Total sugars.	Polarization.		
									Direct.	Invert.	Temperature.
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*°V.*	*°V.*	*°C.*
Wahiawa	127	0.48	.....	7.32	.....	3.57	1.96	5.53	1.0	− 1.5	30.5
Do	128	.44	0.19	5.92	5.00	3.17	.78	3.95	.0	− 1.0	30.4
Do	131	.30	.16	.....	5.07	3.36	.87	4.23	.4	− 0.7	33.7
Do	132	.33	.17	.....	5.10	5.03	1.88	4.91	1.3	− 1.1	30
Experiment station	145	.39	.....	7.44	8.02	3.33	3.14	6.47	2.5	− 1.5	31
Average	.....	.39	.17	6.89	5.80	3.29	1.72	5.01	.....	.....	.....

The above data are interesting as showing the low sugar content of pineapples at this stage of development. None of the fruit examined showed any yellow color, but in each instance the characteristic pale-green color around the basal eyes, which always makes its appearance just before the development of a yellow color, had developed. The appearance of this pale-green color, together with a

flattening of the eyes, is the guide by which the fruit is selected for fresh-fruit shipment. The results show that green pineapples do not contain an excess of acidity or fiber, and from the percentages of hydrolyzable carbohydrates it is apparent that if the fruit is gathered at this stage it can never develop a normal sugar content. Numerous tests at all stages of ripeness have failed to reveal the presence of starch or dextrin in pineapples. It is noteworthy that the ratio of reducing sugars to sucrose at this stage is practically the reverse of that found in the normally ripened fruit.

With the view of determining what changes take place in the fruit in ripening after having been gathered green, a number of pineapples were held at the station until fully ripe. The time required for the completion of this process was usually about three weeks. The following table shows the results of this examination:

The composition of pineapples which ripened after being picked green.

Localities.	Serial No.	Acidity as H_2SO_4.	Fiber.	Solids in juice.	Hydrolyzable carbohydrates.	Reducing sugars calculated as invert sugar.	Sucrose.	Total sugars.	Polarization.		
									Direct.	Invert.	Temperature.
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*°V.*	*°V.*	*°C.*
Wahiawa	133	0.53	0.20	.....	5.32	1.48	3.92	5.40	2.4	−2.6	30.7
Do	134	.60	.21	6.78	3.57	1.13	2.26	3.39	1.3	−1.6	28.4
Do	135	.55	.21	6.04	4.75	1.19	3.17	4.36	2.0	−2.0	32.8
Do	136	.63	.25	6.54	3.75	1.06	2.26	3.32	1.1	−1.8	29.1
Experiment station	146	.49	.....	5.30	.....	1.33	2.06	3.39	1.1	−1.5	32.4
Do	147	.39	.....	5.13	.....	1.27	2.03	3.30	1.0	−1.6	29.2
Do	148	.39	.....	4.99	.....	1.37	1.10	2.47	0	−1.4	31.4

The most important changes which took place in the ripening of these pineapples were the conversion of reducing sugars into sucrose, the development of flavor, and a breaking down and liquefaction of the tissues. True fiber and acidity were not materially changed.

The composition of pineapples, one-fourth ripe, is shown in the following table:

The composition of pineapples when about one-fourth ripe.

Localities.	Serial No.	Acidity as H_2SO_4.	Solids in juice.	Reducing sugars calculated as invert sugar.	Sucrose.	Total sugars.	Polarization.		
							Direct.	Invert.	Temperature.
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*°V.*	*°V.*	*°C.*
Wahiawa	126	0.62	7.34	3.03	3.79	6.82	2.8	−2.0	32
Do	129	.59	7.56	2.53	3.34	5.87	2.2	−2.1	28.4
Do	130	.59	8.36	2.83	3.83	6.76	2.6	−2.3	29.4
Experiment station	149	.72	9.20	2.77	5.89	8.66	4.5	3.0	30.8
Do	150	.75	10.93	2.56	5.25	7.81	4.0	−2.7	30
Average	.....	.65	8.68	2.74	4.42	7.16	.....	.....	.....

These data show that sucrose is developed at a considerable rate during the early ripening process, although the fruit at this time had stored up only about one-half of its normal sugar content.

The next table shows the composition of the fruit when it is approximately half ripe.

The composition of pineapples when half ripe.

Localities.	Serial No.	Acidity as H_2SO_4.	Solids in juice.	Reducing sugars calculated as invert sugar.	Sucrose.	Total sugars.	Polarization.		
							Direct.	Invert.	Temperature.
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*° V.*	*° V.*	*° C.*
Wahiawa	116	0.78	11.83	2.74	7.33	10.07	5.7	−3.6	31.8
Do	117	.67	10.36	2.61	6.70	9.31	5.0	−3.5	31.7
Do	124	.63	.....	2.38	6.83	9.21	4.9	−3.8	30.5
Do	125	.54	.....	4.16	6.09	10.25	5.0	−2.7	32.2
Average	.....	.65	.....	2.97	6.73	9.70	.....	.....	.....

There is a rapid accumulation of sucrose in the ripening of the pineapple. If the fruit is picked at the half-ripe stage and allowed to ripen thoroughly, it will develop a normal flavor and be a highly desirable product.

From the foregoing data it is shown that green pineapples contain a small percentage of sugars, and if gathered at this stage never develop into desirable fruit. As the ripening process proceeds normally, sugars are stored up at a rapid rate, so that by the time the fruit is half ripe it contains a fairly high percentage of both reducing sugars and sucrose; and if gathered and allowed to ripen will mature into a highly edible fruit. The acidity of green pineapples is practically the same as that of the ripe fruit, whereas the ratio of reducing sugars to sucrose is reversed.

As pointed out above, the changes in pineapples that ripen after having been gathered are those of rearrangement, rather than the production of sugars. The composition of the fruit shows that it contains no substance of any consequence that could be converted into sugars, and therefore the total sugar content of pineapples does not increase after being gathered. It is a recognized fact in plant physiology that sugars may result from two different processes—first, from the direct action of chlorophyll in the chlorophyll-bearing cells, and secondly, from a breaking down of other carbohydrates. In some instances there is an accumulation of starch in plant organs which later is hydrolyzed into sugars. In the pineapple, since starch was never found in the fruit, it is safe to conclude that the sugar stored up in normally ripening pineapples is manufactured in the chlorophyll-bearing cells of the leaves and then transferred to the fruit;

hence when the fruit is severed from the stalk all communication with the source of sugar is broken, and therefore its accumulation is permanently stopped.

The cells of green pineapples, as seen under a high-power microscope, contain a thickened layer on the interior of the cell walls, and it is with difficulty that the juice is expressed from the cells. As the ripening process proceeds this thickened layer is gradually dissolved until at maturity the cell walls are extremely thin and easily ruptured. If pineapples are gathered green and allowed to ripen, it has been found that there is a dissolving of this thickened coat on the cell walls, thus apparently increasing the percentage of juice in the fruit without materially changing the concentration of the juice. Later a microchemical study of these changes will be made.

Thanks are extended to Dr. Wilcox for advice and many suggestions in this work; also to Miss Alice R. Thompson for valuable analytical assistance.

REPORT OF THE AGRONOMIST.

By F. G. KRAUSS.

Problems affecting the culture of rice and cotton continue to be the main lines of inquiry of this division, as for several years past.

RICE INVESTIGATIONS.

IMPORTS AND EXPORTS.

The increasing importations of rice from Japan, which amounted to 27,886,102 pounds, valued at $717,064 in 1909, as against 9,656,796 pounds, valued at $221,116 in 1905, has resulted in a gradual and finally a marked decrease in the production of this important crop in Hawaii.

The following table gives the United States customs statistics covering the imports and exports of rice to and from Hawaii during the period referred to above:

Imports of rice into Hawaii.

Year.	Japan.		China.		United States.	
	Amount.	Value.	Amount.	Value.	Amount.	Value.
	Pounds.	*Dollars.*	*Pounds.*	*Dollars.*	*Pounds.*	*Dollars.*
1905	9,656,796	221,116	11,964	245	9,983,491	303,029
1906	12,496,396	283,653	22,600	529	4,129,643	164,683
1907	21,012,842	539,021	13,906	351	755,050	34,144
1908	26,695,642	740,975	6,485	155	95,524	4,821
1909	27,866,102	717,064	13,966	314	109,300	4,358

The exports to the United States from Hawaii during the same period were:

Exports of rice to the United States from Hawaii.

Year.	Amount.	Value.	Year.	Amount.	Value.
	Pounds.	*Dollars.*		*Pounds.*	*Dollars.*
1905	2,771,083	84,414	1908	3,038,624	140,768
1906	5,739,500	223,012	1909	5,823,585	255,210
1907	3,324,107	147,439			

These inroads upon one of Hawaii's staple products are not based upon a competition in prices, but upon quality. The imported product sells at from 25 cents to $1 more per 100 pounds than does the locally grown rice. The Japanese, who are the principal consumers of rice in Hawaii and the sole importers of the Japan products, de-

mand a distinct type of rice whose characteristic culinary qualities are inherent in certain varieties, and also in large part due to the conditions of growth.

RICE IN JAPAN.

With a view of determining, if possible, the varieties and cultural conditions under which the preferred Japan rices are grown, the writer was authorized by the United States Department of Agriculture to undertake such investigations. Accordingly, the fall months of 1909 were devoted to a critical study of the industry in Japan. Valuable data were obtained at several experiment stations, of which the Central Experiment Station at Nishigahara (near Tokyo), the Kinai Branch Station at Kashiwara (near Osaka), and the Kiushiu Branch Station at Kumamoto (in the famous rice region of Kyushu) are worthy of special mention. The last two stations are devoted almost wholly to rice investigations.

At the Kinai Station a fine opportunity was offered to study varieties. Here have been brought all the types of rice grown in the Empire. After six years' study and comparison these have been grouped under 600 more or less constant varieties or strains sufficiently distinct for classification. A hundred of the most distinct types were obtained for experimental purposes, and are now under comparative tests with the best Hawaiian varieties. After inquiry among rice specialists and personal study, the four following standard varieties were determined upon as most promising for Hawaiian conditions, from both culinary and cultural standpoints. The varieties Omachi and Shinriki are the two types now almost exclusively exported to Hawaii, as they find special favor among the large Japanese population, and bring the highest market prices. The varieties Benkei and Miyako are considered of the highest quality in Japan, and are in great demand by those who can afford to buy them. A hundred pounds of choice seed of each of the four varieties were obtained for distribution among Hawaiian growers. Eight prominent growers availed themselves of seed for this spring's planting, and reports of the results of their experiments are now looked for.

The following descriptions of the above varieties are based on a study of pure strains made in the field at the Yamaguchi Demonstration Station, which is situated in the center of the region from which nearly all the Japan rice entering Hawaii is imported, and where these particular varieties are said to attain their highest perfection. A comparison of the behavior of these varieties grown at the station rice trial grounds during the past spring, from the identical stocks described above, should be of value as determining their adaptability to Hawaiian conditions, from the cultural side, at least. Their culinary qualities are, of course, as yet to be determined, and upon this will depend their acceptability to the consumer.

DESCRIPTION OF FOUR NEWLY INTRODUCED JAPAN RICES (PLATE III).

1. Miyako. Average height of plants, 48 inches; inclined to lodge; average number of fruiting culms per clump, 16; panicles large and compact; kernels medium size, awnless; a fair yielder, medium early. Considered the very best variety grown in Japan.

2. Benkei. Average height of plants, 40 inches; stands up well; average number of fruiting culms per clump, 18; panicles compact and heavy; kernels large, awnless; good yielder, early maturing. Considered a promising new variety in Japan, of fine culinary qualities.

3. Omachi. Average height of plants, 48 inches; slightly inclined to lodge; average number of fruiting culms per clump, 15; panicles large but rather loose; kernels medium size, awned; yields well; a type not likely to be appreciated by the Hawaiian grower because of its awned glumes; but strongly recommended by the Japan experiment stations for trial. It is a standard variety of Japan; extensively exported to Hawaii.

4. Shinriki. A standard variety in Japan; largely exported to Hawaii. Of more recent development than Omachi and by some considered an improvement. Average height of plant, 42 inches; stands up well; a heavy tillering sort, averaging 20 to 30 fruiting culms per clump; panicles small to medium; kernels small, awnless; good yielder; classed as a late variety in Japan, but the writer found it maturing at about the same time as the other varieties described above. Considered by the writer a promising variety for Hawaii.

The table below gives the results of the first season's cultural trial of the above varieties in comparison with the old type of Japan rice heretofore grown to a limited extent in Hawaii. The seed was sown February 4, the seedlings transplanted March 15, and the crop harvested June 3, 1910, the growing period being 119 days for all varieties.

Comparative tests of new and old types of Japan rice (spring crop, 1910) grown without fertilization.

Name of variety.	Average height of plants.	Average number of fruiting culms.	Yield of paddy from 100 clumps.	Yield of straw from 100 clumps.	Character of glumes.
	Inches.		*Pounds.*	*Pounds.*	
New types:					
Benkei	28	16.2	4.0	3.28	Awnless.
Miyako	33	16.7	3.75	3.53	Do.
Omachi	31	17.8	4.87	3.61	Awned.
Shinriki	26	23.1	4.23	3.06	Awnless.
Old type:					
Japan rice No. 153	29	19.8	4.15	4.62	Do.

In comparison with the old type Japan rice, No. 153, both Omachi and Shinriki, the two standard sorts in Japan, which are the only varieties imported into Hawaii, outyielded the former. This is in itself a distinct gain should the quality be maintained in future culture. The variety Benkei, which especially appealed to the writer from a cultural standpoint as he saw it growing in Japan, did not quite equal the yield of the old type, but seems promising. Miyako, considered the best type of rice grown in Japan, gave the smallest yield. It is also considered a rather light yielder in Japan, but its

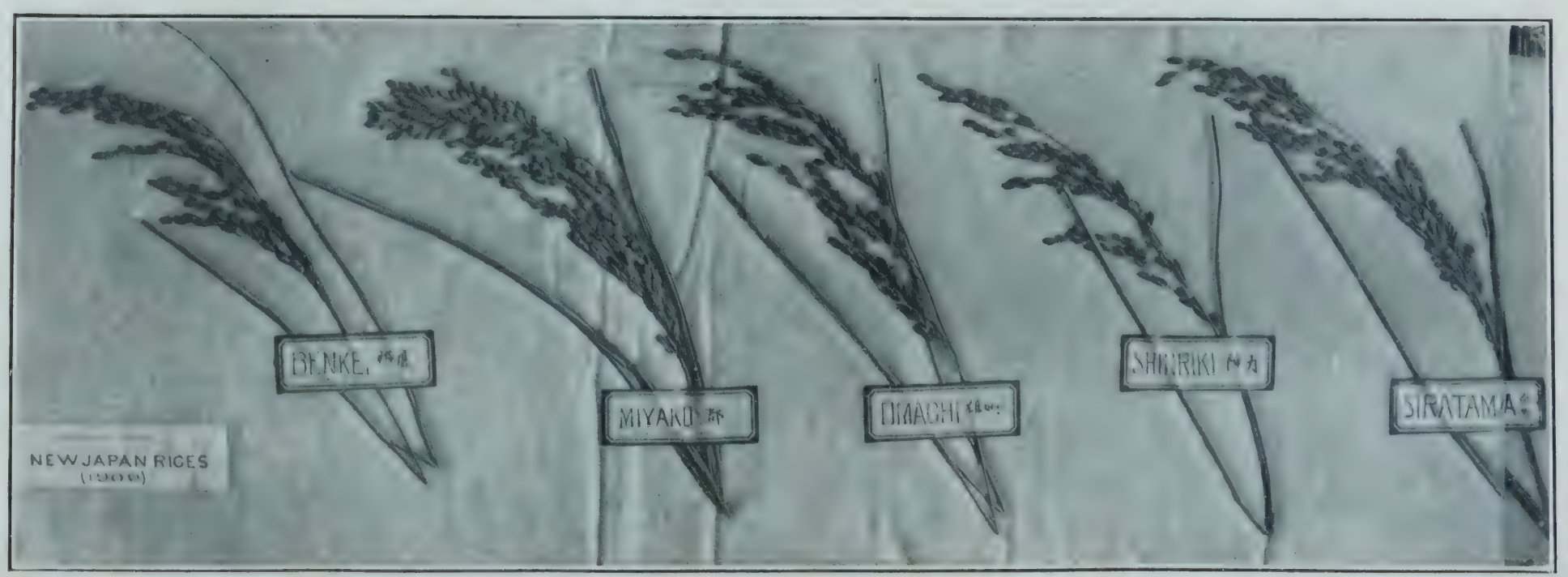
superior quality and consequent high price makes it a leading sort in favored localities. The heavy tillering qualities of Shinriki appear to have been maintained in this trial. From the standpoint of yield, it would appear that Omachi and Shinriki are the most promising sorts. The main objection of the Hawaiian grower to the former variety is its bearded glumes. The Japanese have effected a cross between these two varieties with a view to inducing heavier tillering, beardlessness, and the superior flavor of Omachi in the hybrid. The two former qualities have been effected to a marked degree. Sufficient stock of the hybrid has not yet been grown to make a culinary test. The station was fortunate in securing a small quantity of this hybrid seed for trial.

The figures in Plate III show typical panicles of the several rices just described, and in addition, the variety Saratama, a promising variety, which, owing to its late maturity, can not be described in this report. Panicles of less acceptable types of Japanese rices are shown in Plate IV.

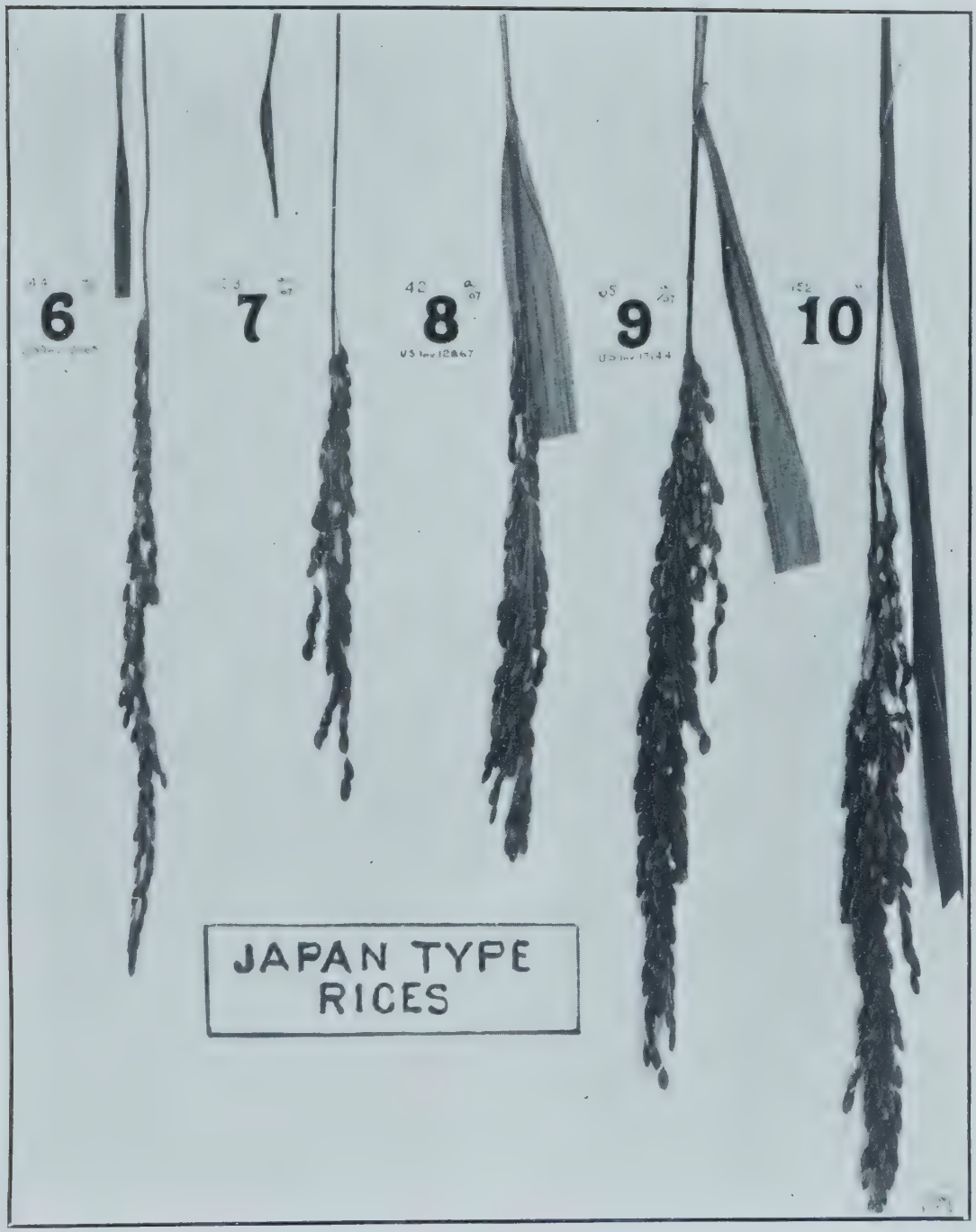
SELECTION AND BREEDING.

In addition to the variety tests of new Japanese and Chinese rices, noted above, the development of pure strains of the best old type is being continued. Some of these strains are now in the seventh generation of selection. A number of these show a marked improvement over the original type, as shown in comparative cultural tests. Increase in yield has been less noticeable than greater purity and uniformity.

Unfortunately, much difficulty has been experienced in inducing growers to perpetuate improved station strains in a pure state. Only limited quantities of station seed are available for distribution, so that growers are dependent upon themselves to produce such seed as they may need for general plantings. However, a season or two of commercial culture almost invariably results in a mixture of varieties. Aside from immediate local benefits, the importance of maintaining pure strains of high-bred rices is well illustrated by a request which came from a rice broker in New Orleans. The station was applied to for samples of choice seed in the hope that a select Hawaiian stock could be obtained to replace the large importations of South American seed used for planting. This is owing to the prevalence of red rice in American seed. A number of local growers submitted samples, but the only stock acceptable was a station strain, for which a substantial advance over current local prices was offered, if obtainable in carload lots. However, too limited an amount was available to make it an object to the purchaser. This experience appears to have renewed the interest in the possibility of growing rice for seed purposes, which has been urged persistently by the



TYPES OF RICE CONSIDERED OF HIGHEST CULINARY QUALITY IN JAPAN.



JAPANESE RICES NOT ACCEPTABLE TO JAPANESE CONSUMER.

station. One grower has asked the station's cooperation in developing this phase of the industry.

Of the several new varieties of rice introduced by the station in past years, variety No. 19 (S. P. I. No. 12508), introduced in 1907, appears to have at last found favor among the more intelligent growers. The Oahu rice mill of Honolulu reports having milled 480 bags, equivalent to 24 tons, during the past season. Other growers and millers are yet to be heard from. Mr. A. Hanneberg, of the Kaneohe Rice Mill Co., who produced several hundred bags of the above lot, speaks enthusiastically concerning this variety and states that it is well suited to the salt-marsh lands, which heretofore were devoted only to inferior rice. Should its adaptability to salt lands and a maintenance of high quality hold true in subsequent practice, a valuable acquisition will have been added to the resources of Hawaii.

Because of the exceptionally heavy tillering, together with the desirable hard, translucent grain of rice No. 19, efforts have for several years past been made to effect a cross between it and the best type of Hawaiian Gold Seed. The latter variety still remains the standard sort with the white and Chinese population, in addition to being one of the leading varieties of export. Could heavier yields and a clearer grain be obtained in Gold Seed, on the one hand, and the fixed property of fall maturity of rice No. 19 be changed to the "all season" cropping habit, which characterizes the Gold Seed, valuable combinations would be effected.

The difficulty thus far has been to get the two varieties to flower at the same time to permit of cross pollination. As the habits are now so well known, it is believed that the extensive plantings planned for this fall will provide the necessary conditions for hybridization.

A careful study was made of the methods practiced by the Japanese in their rice breeding, which has proved very successful during recent years. It is believed that valuable data were obtained as an aid to the contemplated work at this station.

In the study of tens of thousands of individual plants annually by Japanese investigators a natural hybrid among rice was found to be of rare occurrence, notwithstanding the fact that more than 600 varieties have been grown in close proximity for several years past. These results are in agreement with the writer's findings, but contrary to the generally accepted theory.

ROTATION.

The fertilizer investigations with rice having been assigned to the chemical division, this division has had to do with cultural work only. This has included, during the past spring experiments in crop rotation and green manuring, the latter in cooperation with the chemical division. Barley, one of the cereals extensively used in rotation with

rice in Japan, and the established Hawaiian legumes, cowpeas, soy beans, velvet beans, and jack beans (*Canavalia ensiformis*), were planted as rotation crops during the spring, together with the Japanese and Chinese matting plants (*Juncus effusus* and *Cyperus tegetiformis*), which the station has been growing for several years. In addition to the above legumes used as rotation crops, there were planted as green manuring crops *Astragalus sinicus* (the "Genge" or "Renge" of Japan) and *Vicia faba*, the two green-manuring plants most extensively used for rice in Japan. The barleys, of which 50 of the best hulled and naked Japan paddy field varieties were sown, did poorly as a whole, a large percentage failing to head. Some 20 varieties set seed and appear to be fair yielders of grain. All are of very dwarf type, averaging less than 24 inches to tip of spike. Being planted in March, the lateness of season may have had considerable to do with this first poor showing.

Large quantities of barley are imported into Hawaii and its profitable culture in the islands would add materially to their resources. Furthermore, a rotation of a dry-land crop with the submerged culture of rice could not but prove beneficial to the paddy soils, as has been found to be the case in other countries.

The Astragalus used for green manuring proved an entire failure. Planted in March, the seed germinated well, but failed to make more than the feeblest growth. This persisted till the flowering stage and then wasted away, notwithstanding an ample supply of moisture.

The Windsor beans made quite a vigorous growth, but, as in former experimental plantings, failed almost wholly to set seed. It is already quite evident that these two types of green-manuring plants should be planted late in the fall during the coolest season of the year and under moist conditions, such as prevail in paddy fields.

The older-introduced legumes all did well and yielded a large amount of organic matter. Planted in March, the following results were obtained, calculated to acre yields.

Plat III: Soy beans. Variety, Mammoth Yellow; days to turning-under stage, 63; height, 24 inches; yield of green vegetable matter (including main roots), 10,125 pounds; yield as cured fodder (including seeds), 2,500 pounds; yield of seed, 675 pounds; distance of rows, 24 inches.

Plat IV: Velvet beans (*Mucuna utilis*); days to turning-under stage, 75; height of main growth, 28 inches; yield of green vegetable matter (including main roots), 15,300 pounds; yield as cured fodder, 3,420 pounds; yield of seed, 145 pounds; distance of rows, 4 feet.

Plat VII: Cowpeas. Clay type; days to turning-under stage, 75; height of main growth, 36 inches; weight of green vegetable matter (including main roots), 32,400 pounds; yield as cured fodder, 7,200 pounds; yield of seed, 1,417 pounds; distance of rows 4 feet.

Plat VIII: Jack beans (*Canavalia ensiformis*); days to turning-under stage, 75; height of plants, 40 inches; yield of green vegetable matter (including roots), 17,000 pounds; yield as cured fodder, 4,060 pounds; seed not mature at this writing; distance of rows, 4 feet.

Planted March 1, a part of each of the different varieties was turned under about the middle of May, excepting the soy beans, which were turned under 10 days earlier. The jack beans were much the latest to mature, but were turned under with the others to permit of uniform decay before planting the succeeding rice crop.

As will be noted from the above, the cowpeas considerably outyielded all the other legumes, both in green matter and seed. This is in concordance with a number of previous tests in which many different kinds of legumes were under trial. However, both the velvet bean and jack bean are much surer croppers, being practically immune from the attacks of aphis to which the cowpea is especially subject. The main objections to jack beans and velvet beans are their slow maturity and less palatability. The soy bean, because of its early maturity, lends itself well to short seasons and will often fit in where legumes of larger yield but slower maturity would be out of the question.

The matting plants have not yet been harvested, but their growth compares favorably with that previously reported.

COTTON EXPERIMENTS.

Although still in the experimental stage, the cotton industry in Hawaii has made substantial progress during the past year. Many inquiries have come to the station concerning varieties and methods of culture. Station seed has been widely distributed for experimental purposes, enough being sent out to plant several hundred acres. It is estimated that fully 500 acres are now planted in the Territory. The largest planting comprises about 80 acres. The first commercial crop has been harvested, and is now in bale awaiting shipment. Samples submitted to experts have been pronounced first class; the highest market prices have been quoted.

As announced in the Annual Report for 1909, two extensive cooperative experiments on a field scale were begun in the early part of 1909. The first harvest of these has been completed, and the results, although far from satisfactory from the commercial side, are nevertheless of great value from an experimental point of view.

KUNIA COOPERATIVE COTTON EXPERIMENT.

Kunia lies on the east approach to the Waianae Range, at an elevation of about 600 feet. The soil is a deep, light, silty loam. The region would be classed as semiarid, the rainfall averaging less than 20 inches. The natural growth is guava, lantana, klu, and an occa-

sional large kukui tree, Opuntia and algaroba. The grasses are rather sparse, but manienie, piipii, and other native grasses are met with. The whole growth is characteristic of dry regions. No previous crop had been grown on the lands under experiment.

Preliminary to the experiment the land was plowed in October of the previous year to a depth of at least 24 inches, several times harrowed, and finally plank-dragged, which left the soil in fair condition for planting.

On February 16–19 one-fourth acre was sown to each of the following varieties, Caravonica "wool" (Plate V), Egyptian (Mit Afifi), Sea Island (Georgia and Florida strain), Sea Island ("Seabrook"), and upland "Chinese," as an early planting; and a month later another one-fourth acre was sown as a late planting. All varieties were planted $2\frac{1}{2}$ by 5 feet apart, giving 3,480 plants per acre, except Caravonica, which was planted 5 by 10 feet apart, or at the rate of 870 plants per acre. Each plat consisted of an additional half acre, a third of which was left fallow, a third planted to jack beans as a green manuring or rotation crop, and the remaining third was planted to soy beans and cowpeas. This half of each acre plat was then to be followed with cotton in the succeeding year; thus, in the second year (1910), a comparison between 1 and 2 year old cultures was obtained.

The results of the first year's harvests are given in the following table:

Yields of cotton from first year's harvest, Kunia cooperative experiment.

Plat No.	Variety.	Yield of seed cotton.		Yield of lint.	Yield of seed.	Percentage of lint to seed.	Quoted market value of lint.
		Weight at picking ($\frac{1}{4}$ acre).	Weight after 6 months ($\frac{1}{2}$ acre).[1]				
I.	Caravonica "wool":	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Per cent.*	*Cts. per lb.*
	Early planting	$32\frac{1}{2}$	54	24	30	44.4	0.29
	Late planting	22					
II.	Egyptian, Mit Afifi:						
	Early planting	95	131	$44\frac{1}{2}$	87	33.3	.29
	Late planting	$37\frac{1}{2}$					
III.	Sea Island, Georgia-Florida strain:						
	Early planting	107	169	$50\frac{1}{2}$	170	29.4	.31
	Late planting	$64\frac{1}{4}$					
[2]IV.	Sea Island, "Seabrook":						
	Early planting	$397\frac{3}{4}$	392	106	$236\frac{1}{2}$	30.8	.31
V.	Upland, "Chinese":						
	Early planting	$115\frac{3}{4}$	211	71	140	33.6	.15
	Late planting	$119\frac{3}{4}$					

[1] After the first weights were taken the cotton harvested from the early and late planting of each variety was unintentionally bulked together; hence, the cured weights represent the yield of the two plantings—the product of a half acre. To calculate to acre yields, multiply separate plantings by 4, and the totals of the 2 plantings by 2.

[2] Plat IV, consisting of 1 full acre of early planting, was divided into 13 sections for a fertilizer experiment, the detailed results of which will be reported by the chemist in a later bulletin.

The low yields from this experiment may be attributed to several causes. The rainfall, amounting to about 22 inches for the year, was doubtless inadequate for optimum growth on rough and newly

FIG. 1.—CARAVONICA "WOOL" COTTON 6 MONTHS FROM SEEDING.

FIG. 2.—CARAVONICA "WOOL" COTTON 9 MONTHS FROM SEEDING.

COOPERATIVE COTTON EXPERIMENTS.

FIG. 1.—PRUNING 1-YEAR-OLD CARAVONICA "WOOL" COTTON.

FIG. 2.—SECOND SEASON'S GROWTH OF CARAVONICA "WOOL" COTTON.

COOPERATIVE COTTON EXPERIMENTS.

broken ground. Although the germination was excellent, cutworms attacked the young seedlings from their very appearance above ground, destroying as high as 80 per cent of the stand in some cases. This necessitated repeated partial reseeding. In the case of the early plantings, four reseedings were made, and in the late plantings, two reseedings. These reseedings ranged from 20 per cent upward. It will be noted that the late plantings gave much lower yields than the early plantings, and this gives further proof that the great decrease in yield is due to irregularity of stand. It is safe to say that the original early planting outyielded any subsequent plantings twofold, so that a full stand of the first seeding would unquestionably have given fair yields as judged by mainland standards.

Comparatively little damage was traceable to the bollworm. But during the latter part of the season this pest was much in evidence among the general plantings of the development company, whose cotton fields surrounded the experimental plats. The fertilizer experiments gave good evidence of the value of proper fertilization, as has already been pointed out by the chemist in his report.

The importance of selecting suitable varieties is not fully brought out by the table of yields, but a study of the plants in the field indicates that the Upland type, while slightly outyielding the next best in point of yield, gave insufficient increase to make up for the difference in price.

The Egyptian cotton showed fine individual plants, but the poor stand reduced the acre average below all other varieties, except the Caravonica. This latter variety, as is well known, yields poorly the first year, even under favorable conditions.

The best sections in the fertilized Sea Island plat, as well as the best plants in Plat III, containing another strain of Sea Island, give promise for this variety in seasons of average rainfall. This variety should receive further consideration, because of the high quality maintained by the fiber under adverse conditions of growth.

Judged from the standpoint of general growth, and the subsequent heavy squaring of the Caravonica cotton, this variety unquestionably gives the greatest promise as a drought resister, and would seem the variety especially adapted to this locality. Plates V and VI give a series of views of the Caravonica plat. Figure 1, Plate V, illustrates the growth attained at six months from seed. Figure 2 shows the beginning of the harvest, nine months after planting. While the plants as a whole yielded an average of less than 3 ounces per plant, owing to poor stand and irregularity of the remaining plants, a number of selected specimens yielded over 1 pound per plant. Figure 1, Plate VI, shows the partially dormant plants twelve months after planting, as they were being pruned. Figure 2 of the same plate shows the same plants at the present writing, about

eighteen months from time of planting. The plants are heavily loaded with squares, blossoms, and young bolls, from 100 to 500 fruits in the different stages having been counted per plant. Although less than 6 inches of rain has fallen in the past half year, the plants are growing vigorously, and with every prospect of giving a good yield. It is interesting to note that the irregularity in the size of the plants, presented in the first year, has largely been overcome during the fore part of the second season. All vacant places have been filled in by transplanting one-year old stocks which, with few exceptions, are growing well.

On the basis of the results of the past season the company controlling these lands have added 50 acres of Caravonica to the previous plantings, making a total of about 75 acres.

WAIPAHU COOPERATIVE COTTON EXPERIMENTS.

The Waipahu cooperative cotton experiment is located on the uplands bordering the edge of the upper irrigated cane lands of the Oahu sugar plantation, which faces the Koolau Range. This experiment is a duplication of the Kunia experiment, excepting that the entire acre of each experimental plat was sown in two plantings, instead of half that amount, as at Kunia. The elevation is approximately the same, but the rainfall is somewhat greater, estimated to be about 35 inches per annum. However, the land is more exposed to strong cold winds. A tract of virgin grass land, typical of the region, was selected for the experiment. This was plowed to a depth of about 16 inches in October. The old grass stools littered the field badly and it required considerable tillage to get the field in planting condition. All plantings were completed within a week after those at Kunia.

The results of the first year's harvest are given in the following table:

Yields of cotton from first year's harvest, Waipahu cooperative experiment.

Plat No.	Variety.	Yield of seed cotton (½ acre).	Yield of lint.	Yield of seed.	Percentage of lint to seed.	Lint calculated to acre yields.
		Pounds.	*Pounds.*	*Pounds.*	*Per cent.*	*Pounds.*
I.	Sea Island, Georgia-Florida strain:					
	Early planting	62½	19½	43¼	31.2	39
	Late planting	42¾	13¼	29½	30.9	26⅛
II.	Sea Island, "Seabrook":					
	Early planting	277¾	87⅛	190¼	31	87⅛
III.	Caravonica "Wool":					
	Early planting	5¼	2.07	3.18	39.4	4.14
	Late planting	[1] 170	[1] 68	[1] 1.02	40	[1] 136
IV.	Egyptian, Mit Afifi:					
	Early planting	146½	50⅜	95⅛	34.7	101⅛
	Late planting	23½	8	15⅝	34.2	16
V.	Upland, "Chinese":					
	Early planting	113	39¼	73¾	34.7	78⅛
	Late planting	35¼	12¾	22⅛	36.4	25⅛

[1] Weight in grams.

A comparison of the Kunia yields with those obtained at Waipahu shows a considerably lower yield for the latter. This can, to only a small degree, be attributed to lack of moisture, because although the soil became quite dry as the season advanced, certain sections in the fertilizer plat gave yields five times as great as the untreated sections under the same condition of moisture. From this it would appear that in these newly opened lands there exists a decided lack of available plant food. The striking differences between the early and late plantings, which were even greater at Waipahu than at Kunia, are largely to be ascribed to a lack of moisture, since at this season no rains occur. From these experiments and the results obtained during the present season, it would seem that early planting is essential on lands in these localities.

The same drawbacks from cutworms experienced at Kunia were repeated here and necessitated the same number of reseedings. It will thus be seen that this pest in itself is an important problem with the cotton grower. The low yields are, of course, in large part to be ascribed to the poor stands and irregular ages of the plants. This is well illustrated by the fact that the yield of 101½ pounds of lint per acre in the case of the early planted Egyptian cotton, represented about 77 per cent of a full stand, without considering the fact that about 60 per cent of the plants represented a second, third, and fourth replanting. It may be further noted that a large number of individual plants from the first sowing averaged 250 bolls per plant, equivalent to at least 2 pounds seed cotton, which would yield approximately 11 ounces of lint. From the above, and from results obtained at the station trial grounds, it would appear that the Egyption cottons have many qualities to recommend them for trial under Hawaiian conditions.

The Caravonica cotton made a much less satisfactory growth at Waipahu than at Kunia, and the yield was nil for all practical purposes. They again started off slowly during the present spring, but as the warm weather came on, appeared to respond quite markedly. However but few bolls have set, and a number of these are falling prematurely, as is also the case on the acre planting made on a neighboring plantation. The cause for this phenomenon has not as yet been determined.

YIELDS.

No data are at hand to show the exact yields obtained from commercial plantings. Reports of yields up to 1,800 pounds of seed cotton per acre for Sea Island and Egyptian cottons have been received from reliable sources, but the areas under consideration have usually been less than an acre. No official report has as yet been made covering the yields of Caravonica cotton from the 25-acre

planting at Makaweli, Kauai, but it is understood to have been satisfactory for a first season's crop. The cotton from the private planting of 20 acres at Kunia has not been weighed at this writing, but will probably yield at a somewhat lower rate than on the experimental plat.

Mr. E. C. Smith reports that his 40 plants of Caravonica cotton at the Peninsula, planted in January, 1908, have yielded during the 12 months preceding December 31, 1909, 280 pounds of seed cotton. This would be equivalent to a yield of 4,760 pounds per acre.

Owing to the serious infestation with the bollworm of the cottons grown experimentally at the station grounds, the cultural data of which formed the basis of Press Bulletin No. 24, the second year's yield of merchantable lint was very low.

The yields of all the varieties entering the second year promised an advance over the first year. The Florida and Georgia strains of Sea Island matured their first bolls May 10–25, as against August 8 of the previous year; but the bolls, while of good size and yielding an excellent quality of lint, proved to be infested with the bollworm in very large proportions. This increased as the season advanced and prevented the completion of records of yield for comparison with the first year's crops.

The Caravonica cottons, with the exception of test No. 104, fared similarly. Test No. 104, however, which was located in another field, gave good results both in yield and freedom from pests. The 26 plants in this test were planted in July, 1907. The average yield per plant was 15.2 ounces of seed cotton, as against 6.3 ounces the year previous. The three best selections gave the following yields: Selection 5, 2.43 pounds seed cotton; selection 6, 2.5 pounds seed cotton; selection 9, 3.43 pounds seed cotton.

The main lesson to be learned from this experiment is the seriousness of the pest factor, as has already been pointed out by the station entomologist.

COTTON BREEDING.

During the past year a good foundation has been laid for the cotton breeding work planned a year ago, as announced in Press Bulletin No. 24. During the year an acre planting of the most carefully selected Caravonica seed obtainable and a smaller patch of equally good Sea Island were planted for seed production.

Some 30 standard varieties, represented by the American Upland, Sea Island, Egyptian, and Caravonica types, together with the two wild native cottons, and a Cuban red and a Peruvian tree cotton, were planted in a comparative test. All have done well, and all excepting the last four have completed their first crop. Careful study and copious notes have been made of each variety, and a large num-

FIG. 1.—THREE-YEAR-OLD CARAVONICA COTTON TREE BUDDED TO SUPERIOR STRAIN, 3 MONTHS' GROWTH AFTER BUDDING.

FIG. 2.—IDEAL TYPES OF CARAVONICA "WOOL" COTTON BOLLS.
(Two-thirds natural size.)

FIG. 1.—ONE-YEAR-OLD CUTTINGS OF CARAVONICA COTTON.

FIG. 2.—PLANTS GROWN FROM ABOVE CUTTINGS, 6 MONTHS AFTER TRANSPLANTING.

ber of superior individuals selected as breeding plants. All the inferior plants not destroyed outright have been budded over to the selections. Twelve hundred buds were inserted. Of these, 380, representing 31 per cent, have made satisfactory growth. A large number of cuttings were also made. Of these from 10 to 60 per cent took root. While these percentages are low, the material available was not always good. A number of minor trials under more favorable conditions were very successful, exceeding 80 per cent.

Plate VII, figure 1, shows a 3-year-old Caravonica tree budded over to one of the superior selections shown in figure 2 of the same plate. Eight of the ten buds inserted are making a vigorous growth. Plate VIII, figure 1, illustrates average specimens of the 1-year-old Caravonica cotton cuttings, described in the Annual Report for 1909. In this original experiment, 90 per cent of the Caravonica cuttings rooted. Figure 2 shows the same cuttings six months after transplanting to permanent location. They are making a very vigorous growth and are blooming profusely, a number of the plants averaging a hundred young bolls at this writing.

For the propagation of selections by budding it is now planned to grow seedlings of a vigorous sort in the nursery, as with the common fruits, and when these are from two to three months old to bud low to a single stem. This has already been demonstrated as feasible by Mr. E. C. Smith, a pioneer worker with this method. In Mr. Smith's experiments practically every bud inserted has grown. The day seems near at hand when one may purchase budded seedlings of a pure strain of superior Caravonica cotton by the hundred or thousand. These would be planted out in orchard rows like so many fruit trees, and a full year of cultivation saved, with a possible saving in cost.

MISCELLANEOUS CROPS.

In addition to the comparative tests of rices and cottons, the usual plantings of new crops, to test their adaptability to Hawaiian needs and conditions, have been under trial during the past year. The number of varieties under test during the past spring has exceeded 200. A large proportion of these was personally selected in China and Japan. Among the above a number of sorghums from Africa, and legumes from Japan, give special promise. These will be reported upon in a forthcoming bulletin.

During the year numerous calls were made upon this division for advice pertaining to problems affecting field crops other than rice and cotton. Among these may be mentioned an extensive cropping system involving a 50-acre cooperative experiment, which was planned for the Molokai Ranch Co. This experiment is now well under way, and is showing substantial results.

TARO.

The gradual decline of the taro crop on a 9-acre plantation near Honolulu has been given some attention during the year. An investigation of the fields during the height of the harvest season a year ago showed a deplorable state of affairs. Different patches showed from 20 to 60 per cent of the corms, the edible underground portion of the plant, to be decayed. The decayed portions were returned to the patches "as fertilizer," and in replanting the "hules" from diseased plants were freely used. No fallowing or rotation had been practiced for 20 years. Such a practice could not be expected to bring about other results. The general treatment outlined in Bulletin No. 2 of the station, entitled The Root Rot of Taro, by the former agriculturist, was recommended. The results thus far are very encouraging. Not more than 5 per cent of diseased plants are apparent at this time, a year after the treatment began.

The agronomist wishes to make acknowledgment of the financial aid and encouragement rendered by a number of the prominent rice growers of the Territory in furthering the rice investigations in China and Japan. Likewise thanks are due to the Japanese and Chinese officials who freely gave information and seeds during the oriental trip. To the members of the station staff who have made valuable suggestions and rendered material aid in various phases of the work in hand, and especially to my former associates, Messrs. Q. Q. Bradford and V. S. Holt, I wish to express my appreciation for their work on cotton. The former did practically all the budding.

A full report of the writer's observations on rice and cotton investigations in China and Japan appeared in The Hawaiian Forester and Agriculturist, beginning with the May, 1910, issue.

○